Astronomy

AUG 2 1943

Sky and TELESCOPE

In This Issue:

Know Your Sundials

A Remarkable Library

Soliloquy of a Variable Star Observer

The Answer's in the Sky

Air and Sea and Sky

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Vol. II, No. 10
AUGUST, 1943
Whole Number 22
20 cents

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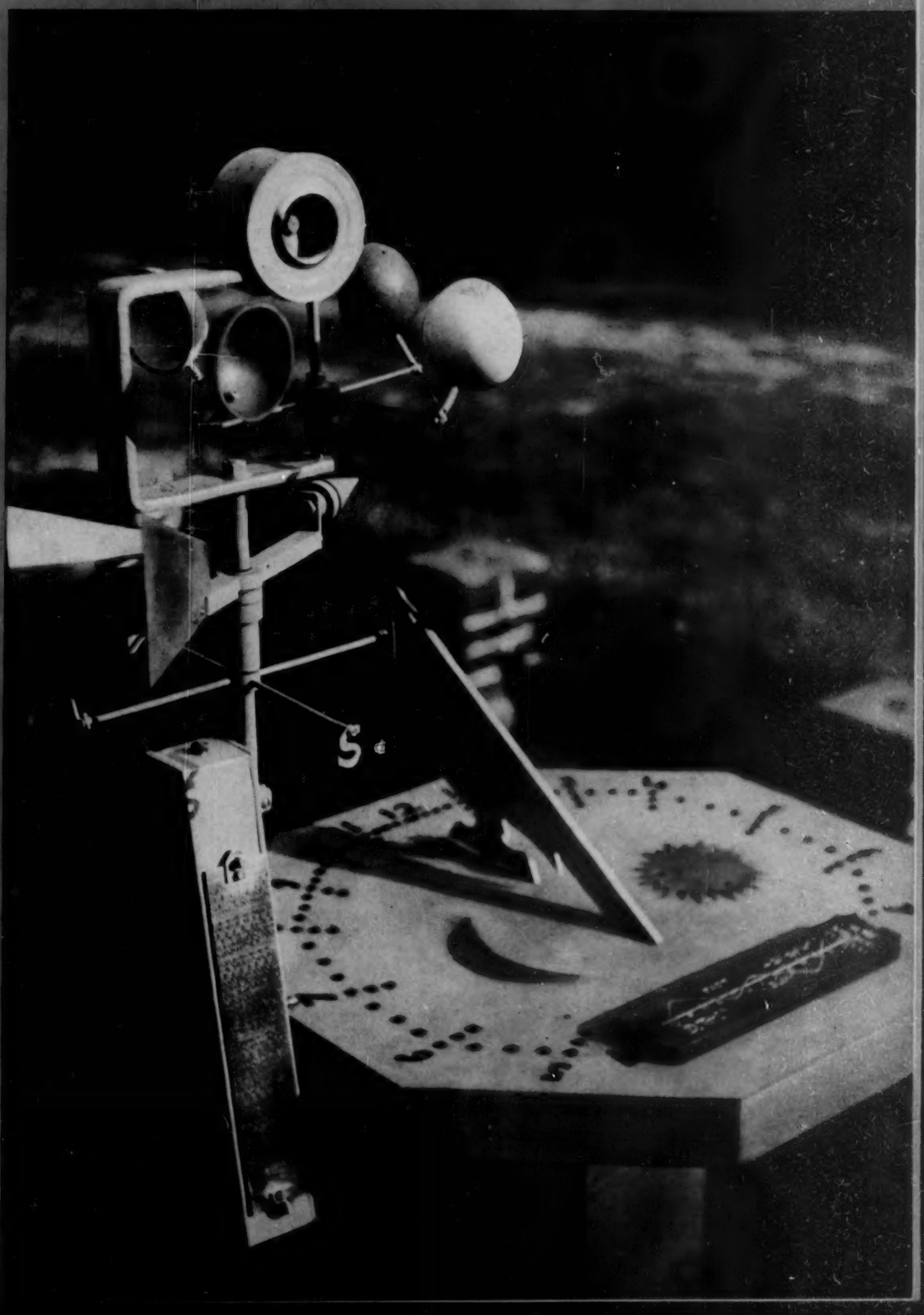

A modern sundial, with attachments for weather observing.

The Editors Note . . .

ALTHOUGH many astronomers are away from their observatories, the number of contributions to popular astronomical literature does not seem to have diminished. These are not confined to the purely astronomical publications, so the following list of outstanding articles which have come to our attention may be of interest to the amateur who wishes to keep thoroughly up-to-date in astronomy and allied subjects. For convenience, the articles are arranged by publication; the selection is purely arbitrary and the list cannot be considered complete.

Scientific Monthly (A.A.A.S., Washington, D. C.). Jan. '43 is Vol. LVI, No. 1.

Present State of the Theory of Stellar Evolution. Henry Norris Russell. Sept. '42.

Recent Advances in Our Knowledge of the Photographic Process. C. E. Kenneth Mees. Oct. '42.

Temperature and Average Precipitation Contrasts in the United States. Stephen S. Visher. Sept. & Nov. '42.

Edmond Halley, 1656-1742. N. T. Bobrovnikoff. Nov. '42.

Cosmic Emotion. Paul R. Heyl. Dec. '42.

Problem of the Expanding Universe. Edwin Hubble. Jan. '43.

Meteorites and the Moon. H. H. Nininger. March '43.

Newton's Philosophy of Nature. Louis T. More. June '43.

Artificial Radioactivity and the Completion of the Periodic System of the Elements. E. Segré. July '43.

Popular Astronomy (Carleton College, Northfield, Minn.). Jan. '43 is Vol. LI, No. 1.

The Meteoritic Origin of Lunar Craters. Ralph B. Baldwin. Aug. '42 and March '43.

Early American Astronomy. H. B. Rumrill. Oct. '42.

Astronomy in the Service of Culture. Roy K. Marshall. Jan. & Feb. '43.

Navigation with a Watch. Charles H. Smiley. March & May '43.

Photographic Determination of Stellar Masses. Peter van de Kamp. April '43.

Telescopic Magnification and Eyepieces. H. B. Rumrill. April '43.

The Story of Pleione. Otto Struve. May '43.

Reminiscences. Tilton C. H. Bouton. May '43.

"Copernican Quadricentennial Issue." June '43.

Astrophysical Journal (University of Chicago Press). Jan. '43 is Vol. 97, No. 1.

The Crab Nebula. W. Baade and R. Minkowski. Sept. '42.

Development of the Coronaviser. H. W. Babcock. Sept. '42.

Spectrophotometric Observations of the Light of the Night Sky. C. T. Elvey and Alice H. Farnsworth. Nov. '42.

(Continued next month)

Sky and TELESCOPE

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In Focus

FEATURED in this issue is an article on the classification of sundials. The illustrations show many different forms and types of dials, with which the reader may compare his previous impression of the average sundial. Perhaps the sundial pictured on the front cover appears more conventional — Mr. Mayall classifies it as HORIZONTAL — its flat dial plate and style pointing to the celestial pole seem usual enough.

The beauty of this simple dial and its unusual furniture pay tribute to the ingenuity of Mr. Witherspoon, who describes his dial and accessories as follows:

"The dial plate is equipped with a time-correction (equation of time) graph, which will enable a correction to be applied to the apparent solar time reading of the dial in order to procure watch time. A bird design has been built into the gnomon. The figures are of copper imbedded in the smooth cement surface of the dial plate.

"The anemometer [wind-measuring instrument] has a tachometer [counting device] attached to its shaft by a slip joint; the lower end of the shaft has a hardened pivot seat. There is a pendulum mounted on the side of the dial plate, and its case carries a scale to reduce revolutions per minute to miles per hour. Both tachometer and pendulum are protected from the weather by covers provided with glass windows. Ball bearings are introduced where needed, and all lubrication is by wick feed.

"The anemometer is accurate, but the sundial varies about two or three minutes. I think this error cannot be reduced by further adjustments — the width of a pencil mark in laying out the dial would be about that much in the final reading."

Many amateur astronomers are turning to the fascinating hobby of making and collecting sundials. Try one in your victory garden!

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The Stars for August 21

BACK COVER: The Trifid nebula, M20, in Sagittarius, is a striking example of a diffuse nebula, with bright and dark formations. Photographed with the 60-inch reflector, and an exposure of $2^h\ 26^m$, at Mt. Wilson Observatory. Located very near the position of the winter solstice, M20 is also close to the larger Lagoon nebula (M8). They lie in a region containing a great deal of obscuring matter, which may indicate that they are but illuminated parts of an extensive nebulous region. Mt. Wilson Observatory photo.

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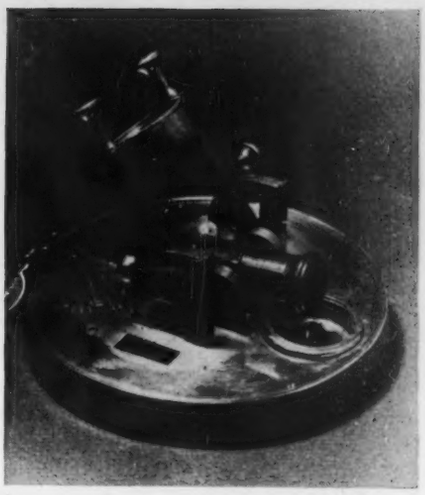
KNOW YOUR SUNDIALS

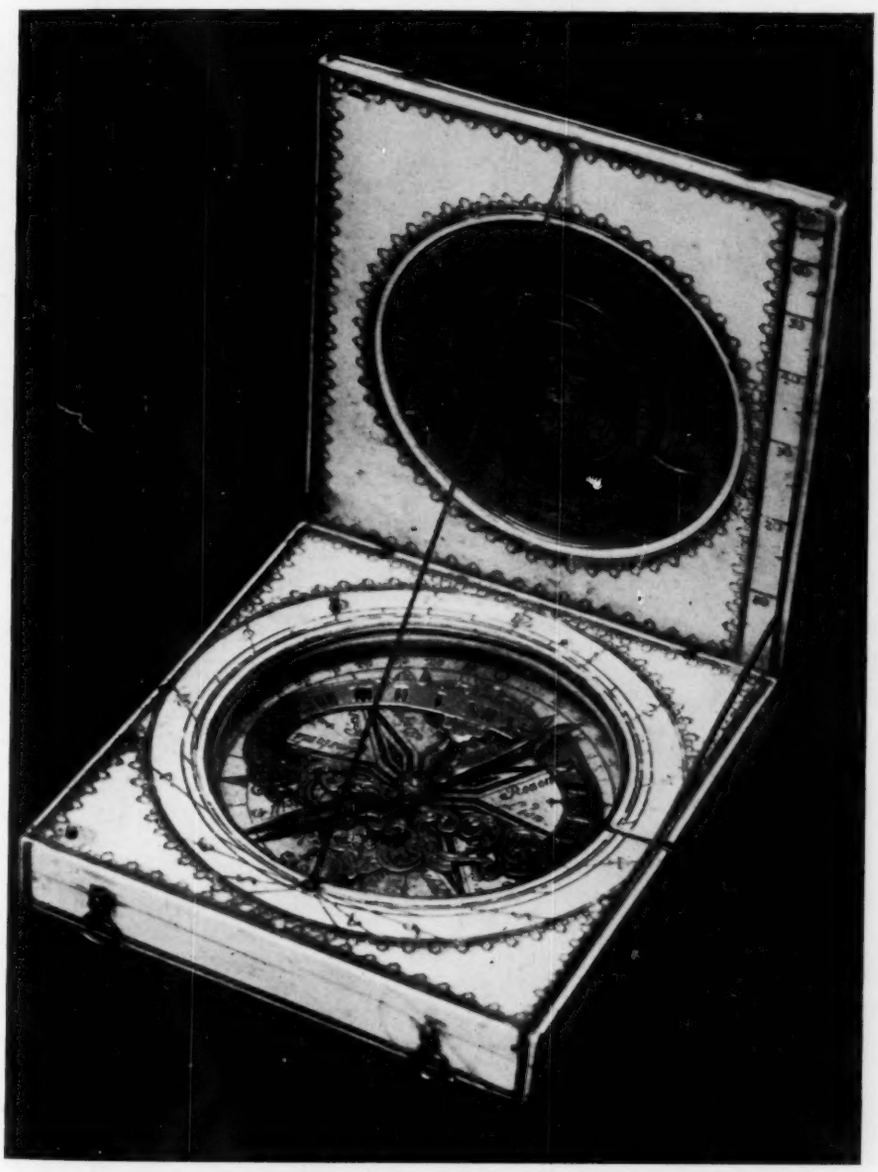
By R. Newton Mayall, *In charge of the Ernst Collection, Harvard College Observatory*

THE SUNDIAL is the oldest scientific instrument to come down to us unchanged through the centuries. This ancient device was also man's first concrete application of his knowledge of the motions of celestial bodies. Even in its crudest stage of development, the sundial was delineated with remarkable exactness; and through the centuries it has kept pace with man's ever-increasing demands for greater accuracy in timekeeping.

Portable dials, which are of particular interest to present-day collectors, seldom exceed five or six inches in the largest dimension and a great majority of them fit easily into one's vest pocket. Because these small instruments were made to be used as we use a watch today, we find great variety in type, workmanship, form, size, and materials. Indeed, it is hard to recognize some of them as sundials. Master craftsmen of all periods have contributed to their manufacture, but the connoisseur seeks those made during the three centuries from 1500 to 1800. That period marks the culmination, after centuries of development, of the art of making sundials, when such men as Tröschel, Schissler, LeMaire, and Beringer were producing their masterpieces.



SIGNAL GUN (Altitude) Light. This dial (about 4/7 actual size) is probably French, late 19th century. The focusing lens is supported by the two prongs. Note the small horizontal dial below them, and the compass under the gun.

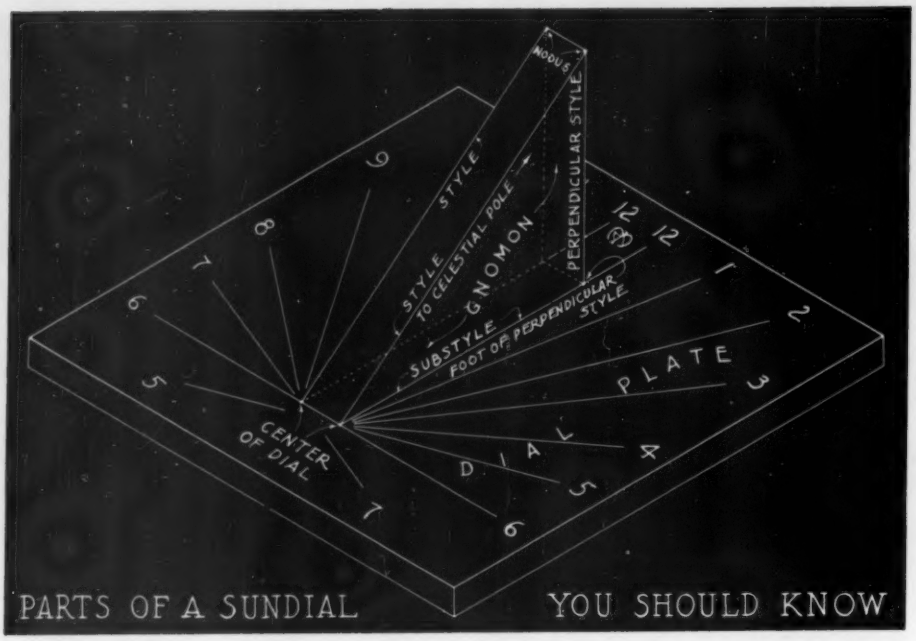


ANALEMMATIC — France — about 1675. An ivory dial, made by Charles Bloud (full size reproduction) has an inner, azimuth dial with a movable hour band. The vertical plate contains a lunar phase calculator for determining time by moonlight.

When Harvard College Observatory acquired the Ernst collection of portable sundials, it became apparent that something should be done to make the instruments intelligible to the layman. With so many different-looking instruments displayed in one place, the obvious question is, "What kind of dial is it?" That question is usually followed by "How is it used?" "How does it tell time?" and "What tells the time?" The first question is the most important; answers to the others make it possible to distinguish one dial from another of similar appearance but different in method of telling time. Any attempt to answer these questions leads directly to the subject of classification.

Not long ago I was glancing over the catalogue of a fairly large collection of sundials. Six instruments attracted my attention and I noted them as they were listed, thus: 1, *Horizontal Dial;* 2, *Compass Dial;* 3, *Tablet Dial;* 4, *Pocket Dial;* 5, *Octagonal Dial;* 6, *Ivory Dial.* The description accompanying each piece shows that all of them are placed in a horizontal position when in use; all tell time in exactly the same manner; all are made for use in particular places; and all have compasses. One might expect six different types of dials, but they differ only in form, material, and maker.

Classifying pieces in any collection requires some knowledge of the subject concerned. In the case of sundials you should be familiar with certain parts, and the principle upon which the instru-



The most frequently misused terms are gnomon and style. The gnomon is the structure that supports the style, and the latter is that edge actually used to indicate the time, either by shade or light. If a thread is used, the style is considered coincident with the gnomon. The style is part of the gnomon. The dial plate is the plane upon which the hour lines are inscribed. The substyle is the line upon which the gnomon is erected, perpendicular to the dial plate. The nodus is a specific point on the style whose shadow is generally used to indicate the days of the year or the altitude and azimuth of the sun by means of the position of its shadow on the dial plate. The nodus may be a notch, hole, ball, bead, or knot.

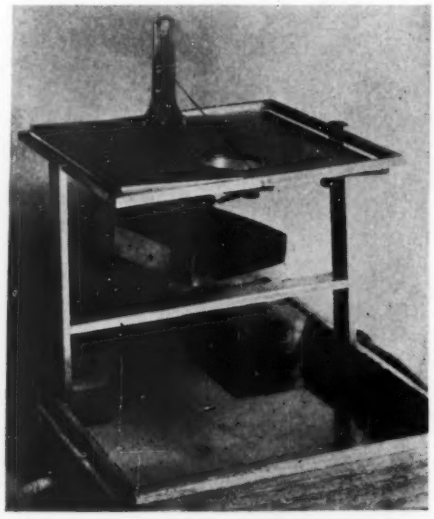
ment works. The fundamental parts, common to all dials, are *style, gnomon, dial plate, substyle,* and *nodus.*

The basic principle of the sundial is the same as that for watches and clocks. The sun is assumed to travel at a uniform rate along the celestial equator, thus marking off equal intervals of time.

With this principle in mind, you can readily see that a broom handle stuck in the ground and tilted to point to the celestial pole lies parallel to the earth's axis, and the sun appears to rotate about it as a center. This and the fact that the tilt of the broom handle always equals the latitude of the place (or the height of the celestial pole above the horizon) are the two basic elements in the construction of a sundial. All dials are constructed on this principle whether or not they actually have a line or edge that points directly to the pole of the sky. An example is the pillar, shepherd, or poke dial, wherein no style pointing directly to the celestial pole is visible. This is because the dial actually tells time by measuring the height of the sun above the horizon rather than by measuring the sun's distance on the equator from the true south point, as is the case in horizontal dials usually found in gardens.

In the case of the broom handle, all you have to do is to find points on the ground directly in line with the sun and broom handle, and you have a sundial, provided you space your points on the ground in accordance with the hourly positions of the sun. Naturally, the broom handle will cast a shadow which will be in direct line with the sun. In this manner a dial can be laid out on any surface, flat, sloping, curved, or otherwise, because the relations between certain parts of the dial (such as the gnomon, style, substyle, and dial plate) are fixed for all dials, whether spherical, conical, or plane; and whether shade or light is used as an indicator.

Therefore, it is possible to use the dial plate to determine the type. This procedure is rigidly adhered to, except in a few instances where the form is such that a more descriptive term is used to identify a special type. The armillary, for example, has a very definite form, although the dial plate is "equatorial," that is, it lies parallel to the plane of the equator.



HORIZONTAL, Noon Mark. A Japanese dial (1/3 size) of about the early 18th century. Observe how it is mounted on gimbals and equipped with a weight for use at sea.

In order to determine the type of a sundial, it is necessary to know only the position in which the dial plate lies when in use; and the form or appearance of special dials like the armillary. Basic type nomenclature, descriptive of the position or form, is used in the following discussion of various types in which all dials can be placed. The special group comprises those dials which require detailed explanation or specific definition. The accompanying chart lists these basic and special types in full capitals. Their descriptions follow:

Ordinary Types

HORIZONTAL. The most prevalent of dials. May have multiple hour bands; a fixed or folding gnomon; style, solid or thread. Usually fitted with a compass (portable form). For universal use, fitted with fixed style, quadrant, and single hour band.

VERTICAL. These dials are upright and face the cardinal points of the compass. Usually single hour band with fixed style. On north and south dials the substyle lies in the plane of the meridian (12 o'clock line). The east and west dials have parallel hour lines and a fixed style elevated above and parallel to the dial plate. Substyle is the 6 o'clock line.

DECLINING. Vertical dials that do not face the cardinal points of the compass. The substyle is not the 12 o'clock line (meridian).

RECLINING. Usually found on multiface dials (see below) and often used on sloping roofs, wall copings, and so forth. They face the cardinal points of the compass and lean from you as you look at them. The polar and equatorial (see below) are reclining dials, but they are separated and named in accordance with the plane in which they lie. The north and south recliners have the substyle on the 12 o'clock line. The east and west recliners have the 12 o'clock line horizontal, and the substyle is not the 12 o'clock line.

INCLINING. Usually found on multiface dials. These are similar to the reclining dials but lean toward you as you look at them. They face the cardinal points of the compass.

DECLINING-RECLINING. These are neither vertical nor do they face the cardinal points. The 12 o'clock line is not perpendicular and the substyle is not the 12 o'clock line. Usually found on multiface dials, but also used on roofs, wall copings, and so forth.

DECLINING-INCLINING. These are the opposites of the declining-reclining dials and are similarly identified. Usually found on multiface dials.

EQUATORIAL. The hour lines are

KEY TO MAYALL SYSTEM OF CLASSIFYING, LABELLING, AND CATALOGING SUNDIALS

5"

3"

NO. TYPE , USE (METHOD) INDICATOR-COUNTRY-DATE

MATERIAL _____ SIZE _____

MAKER

DESCRIPTION

NOTE-"Material" refers to dial plate only.

NOTES

OUTLINE CATALOG CARD
(Standard Library Index Card)

FOR LABELS

Use information given on first line of catalog card. See also outline below, keyed to divisions.

If space permits, maker's name and other interesting features may be added.

OUTLINE FOR LABEL
(NUMBERS KEY TO DIVISIONS LISTED BELOW)

0 1 2 3 4 5 6
NO. TYPE, USE (METHOD) INDICATOR - COUNTRY - DATE

① LIST OF TYPES

Ordinary	Special
HORIZONTAL	HORIZONTAL-VERTICAL
VERTICAL	ARMILLARY
DECLINING	ANALEMMATIC
RECLINING	SIGNAL GUN
INCLINING	CONICAL
DECLINING-RECLINING	CONCAVE
DECLINING-INCLINING	CONVEX
EQUATORIAL	NOTE: Use capital letters for division 1. Use capital and lower case for divisions 2,3,4, and 5.
POLAR	
MULTIFACE	

② USE
(Preceded by comma)

a- Particular place or places (omit)
b- Universal
c- Specific (such as "Noon Mark")

③ METHOD
(Always in parentheses)

a- Hour angle (omit)
b- Altitude
c- Azimuth

④ INDICATOR

a- Shade (omit)
b- Light
c- Magnetic

COMMON FURNITURE

Compass
Windrose and Vane
Lines of Declination
Lines of Altitude
Lines of Azimuth
Signs of Zodiac
Lunar Calculator (two types).
Nocturnal
Babylonian Hours (1-24, Sunrise to Sunrise)
Italian Hours (1-24 sunset to sunset)
Jewish Hours ("unequal", 1-12 sunrise to sunset and Sunset to sunrise. Also on Oriental dials).
Calendars
Analemma (various forms).

equally spaced except in certain cases such as those dials in the form of a star or a cross. Other common forms include concave and convex half-cylinders or bands, full and split rings, convex and concave hemispheres, and globes. For universal use, fitted with a quadrant. May be inscribed on upper and lower surfaces of the flat plane variety. In the case of rings, either a double-needle gnomon is used or a single reversible needle, or a pinhole sight. Some — particularly standard-time dials and heliochronometers — are fitted with an alidade (sighting device). See also RECLINING above.

POLAR. The hour lines are parallel. Fixed style elevated above and parallel to dial plate. For universal use, fitted with quadrant. Usually found on multiface dials. Dial plate lies parallel to axis of the earth. See also RECLINING above.

MULTIFACE. These dials comprise only those solids (or hollow solids) with two or more faces inscribed with hour lines. A common form is the cube, which is also made for universal use (fitted with quadrant and plumb). Combination dials such as horizontal-polar-equatorial, or horizontal-vertical-equatorial, belong in this class and may be found among stationary dials.

Special Types

HORIZONTAL-VERTICAL. A definite type of portable dial, usually in the form of two hinged tablets. The horizontal dial plate often has multiple hour bands. Solid or thread gnomon. For universal use, fitted with quadrant and single hour band. The universal type is rare, but was recently brought into use in exploration. Stationary dials of this type are few.

ARMILLARY. A definite form comprising a system of rings (from two to 10), corresponding to the major circles of the terrestrial and celestial spheres. The axis of the sphere is the style. Hour lines are equally spaced on the equatorial band or ring. For universal use, the meridian ring is graduated in degrees. Often a ray of light serves as an indicator, passing through a pierced slide that may be adjusted to the proper day of the year.

ANALEMMATIC. A specific type of horizontal dial comprising a combination of HORIZONTAL and HORIZONTAL (Azimuth) (see below). Easily distinguished by the elliptical form of the hour band and the perpendicular style which moves in a north-south direction on the meridian or minor axis of the ellipse. The style (here coincident with the gnomon) is set to the corresponding day of the year. If the elliptical band is a separate dial by itself, the class is then HORIZONTAL (Azimuth).

SIGNAL GUN. Often combined with a horizontal dial. A lens is used to focus the sun's rays on the touch hole of a cannon which is so placed that the charge is set off at noon, apparent time. The lens is adjustable to the declination of the sun.

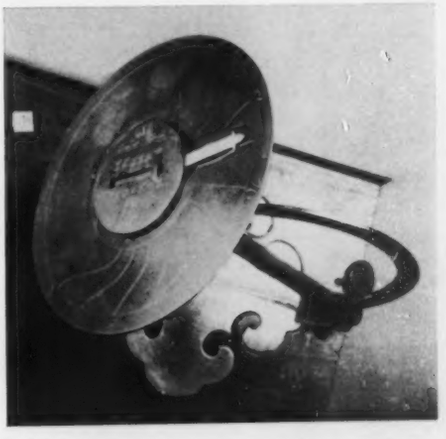
CONICAL. Comprises all dials in the form of a cone, either partial or full. The so-called goblet or chalice dials are conical dials. They tell time by recording the altitude of the sun, and they are easily distinguished. A vertical pin in the center, or the edge of the rim, may be used to cast the shadow.

CONCAVE. This type includes those dials inscribed on concave surfaces that cannot be relegated to one of the foregoing types. Many equatorial dials are concave but the position of the dial plate determines the type. The ancient hemisphere of Berosus is typical of the concave type, as are many of the "sunk" dials of the Renaissance, which were hollowed out of their supporting blocks.

CONVEX. Includes dials on convex surfaces that cannot be placed in one of the above types. Many equatorial dials are convex.

SUCH are the so-called basic types. All dials can be ascribed to one type or another, but it is a general classification which does not definitely identify an individual dial. In a group of vertical dials, some may be flat, others round; the hour lines may be straight or curved; and the means by which the time is recorded may be different. Therefore, certain additional data are necessary to define clearly an individual piece. This is provided for in the classification by referring to three things: *use, method,* and *indicator.*

Use. Some dials are to be used in a particular place or places. Such dials are easily recognized by the single hour band,



EQUATORIAL. This Japanese dial (about half size) has an adjustable pointer for use with unequal hours.

or multiple bands, usually three, four, or five. In the case of multiple bands, each is labeled by a figure noting the latitude in the vicinity of which it is to be used for telling time. Dials that may be used anywhere are called **universal** dials. They are usually fitted with a quadrant and plumb, or some other means of adjusting the dial plate to any latitude. Then there are dials designed for **specific** purposes, such as the noon mark, which is used to record only the noon hour.

Thus a horizontal dial is just a plain dial to be used in one or a few specified places; or it may be a HORIZONTAL, Universal, for use anywhere; or it may be a HORIZONTAL, Noon Mark, to determine midday.

Method. This refers to how the dial tells time — by measuring the **hour angle, altitude,** or **azimuth** of the sun. The common horizontal dial tells time by recording the hour angle of the sun, that is, the angle (measured in time) on the celestial equator between the sun and the true south point of the celestial equator. This method is most common.

Many interesting dials tell time by measuring the altitude of the sun (angular height above the horizon). Typical is the cylindrical dial, with a gnomon which projects outward from and at right angles to the side of the cylinder. This cylinder is marked with vertical date lines (over which the gnomon must be placed, by turning the knob at the top), cut by curved hour lines. Similar dials will be found in the form of disks, quadrants, or rings. Because the portable kinds are usually suspended when in use, they are called VERTICAL (Altitude). Regardless of the position in which they lie, they may be recognized generally from the oddly shaped hour lines cutting across date lines. The point of the gnomon is the style.

The angular distance, measured on the horizon, between the south point and the foot of the perpendicular from the sun to the horizon is called the azimuth. Dials that use this method to record the time are called azimuth dials. Like altitude dials, they can be recognized generally by wavy hour lines crossing date lines. The gnomon is usually a pin.

Indicator. The device used to indicate the time is called the indicator, and may be **shade, light,** or a **magnetic needle.** The first two are obvious, but the latter is not so easily determined. Dials of the magnetic type look as though the gnomon had been lost. Such dials are rare. They would, of course, be classified as HORIZONTAL (Azimuth) Magnetic. The hour lines are wavy and cut by date lines. A magnetic needle is mounted in the center. The whole is mounted in a square block, which, when turned until the east and west sides cast no shadow, will allow the needle to indicate the time.

IF THERE can be glamour in sundials, it will be found in those that have other lines and parts in addition to the gnomon, hour lines, and style. All such parts or lines not essential to the primary function of the dial are called *furniture.*

VERTICAL (Altitude) — French — early 18th century. This boxwood dial (1¾ times full size) is the so-called shepherd, poke, or pillar dial. The gnomon projects horizontally.

On stationary dials, the common furniture includes lines of declination, signs of the zodiac, an analemma, lines of altitude and azimuth; but on portable dials the common furniture includes all of the foregoing together with the compass, windrose and vane, lunar calculators (two types), nocturnal, Babylonian hours, Italian hours, Jewish hours, and perpetual calendars of various sorts.

Lines of declination, altitude, and azimuth, can be deciphered by a casual inspection of the dial and gnomon. They are usually numbered in degrees and/or days. The days usually refer to the equinoxes and the solstices, but frequently the 20th or 21st of each month is noted. Lunar calculators are of two kinds — those that require a previous knowledge of the age of the moon; and those by which the age of the moon can be determined (often called lunar phase dials). The calculator is used to determine the time (without mental calculation) by observing the shadow cast by moonlight on the ordinary sundial. Either type will have a circle divided into 29 or 29½ parts.

The nocturnal is not a sundial. It is a portable or stationary dial used to tell time at night by means of the stars. It consists of a base plate or disk, bearing the days of the year, on which a rotating hour disk and an alidade are mounted. A hole is made in the center. The nocturnal is usually calculated for use with the pole star and one or both of the Pointers in the Big Dipper, or the pole star and the brightest star in the bowl of the Little Dipper. The hour disk may be notched to permit reading the time in the dark by counting the number of notches between the reference point of 12 and the sighting edge of the alidade. The instrument is frequently incorporated in portable sundials.

The Babylonian, Italian, and Jewish hours may be recognized by their appearance and the accompanying numerals. The Babylonians counted their hours continuously from one to 24 from sunrise to sunrise; the Italians counted theirs continuously from one to 24 from sunset to sunset. Thus the Babylonian hours are noted from 24 to 12, whereas the Italian hours are noted from 12 to 24. The Jewish hours are frequently referred to as the "old unequal planetary hours" or as the "temporary" hours. This arises from the division of the day from sunrise to sunset into 12 equal parts. Because this period varies in length, the summer daylight hours will be of longer duration than the winter hours. Similarly, the hours of night will be just the reverse — longer in winter than in summer.

Calendars are of many different kinds serving many different purposes — from fixed annual calendars to perpetual, and from the simple to the complex. Some enable one to determine for any given year the golden number, dominical letter, epact, cycle of the sun, the time of new moon, and so forth.

The analemma is a device used to make a sundial record local mean time, or standard time. It usually appears in one of two forms, as a figure eight, or linear (in the form of a scale). Sometimes a two-dimensional chart or a table is appended to the ordinary dial. In other dials, the analemma is incorporated in the hour lines, causing a deformation, in which case it is not classed as furniture.

Furniture is most prevalent on European dials. Oriental dials seldom have furniture, except for the compass. Lunar calculators and calendars will be found occasionally on Oriental dials.

Know your sundials — know their types, how they are used, and how they tell time. And know that collecting sundials is a fascinating hobby, whether you consider them as *objets d'art* or as scientific instruments; whether you collect them for educational purposes, or just for fun.

In the region of the northern Milky Way, countless stars and bright and dark nebulae send us continual messages of light. At the top is Deneb, and nearby is the famous North America nebula. At the bottom, below Epsiion Cygni, are some portions of the wispy Veil nebula. Photo by L. P. Tabor at Cook Observatory.

A REMARKABLE LIBRARY

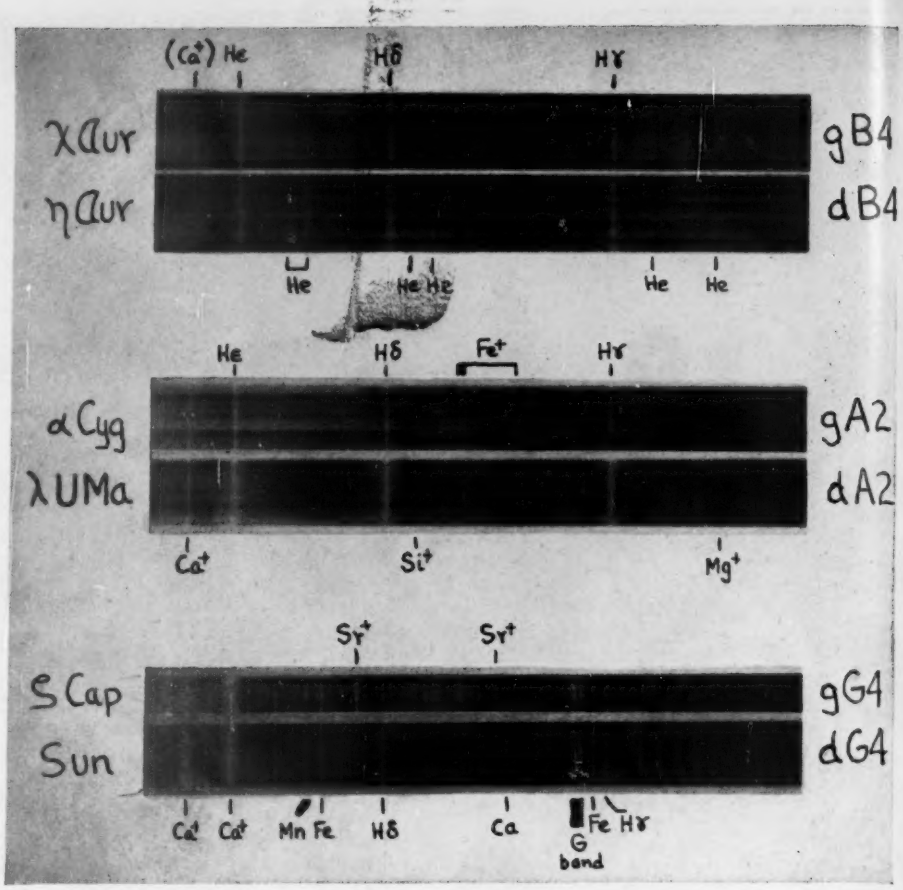
By Keivin Burns, *Allegheny Observatory*

WHEN the light from a star falls upon a photographic plate, there is much that it tells us about the star at once. If we can imagine a plate to be as much faster than the eye as the eye is faster than our best plates are now, then we might say that the whole story would be told instantly. The eye uses the energy in a train of waves 1,500 to 6,000 kilometers long in seeing a moderately faint detail; the best plate for the region of the eye's greatest sensitivity requires the energy from a wave train hundreds of millions of kilometers long to register this feeble illumination. We are able to photograph some laboratory phenomena which last only 1/300,000 of a second, long enough for a wave to travel one kilometer. Even shorter exposures are probably possible. It does not strain the imagination too

far to suppose that under some conditions we might be able to register phenomena in a train only a few meters, or even only one meter, long. In that case, we should only need the energy traveling through a cubic meter to tell us all about the star under examination.

Let us discuss the various things which we can learn about a star from one observation. First, the important datum, its apparent brightness, is shown at once. In practice, we do not usually fix a value of a star's brightness by a single observation, but study the star over a number of days or years, to be sure that it is not one among the few per cent whose brightness is variable. Another important datum which might under ideal conditions be determined at once is the star's position, which would be shown by the circles on the observing instrument; or its position relative to other stars in the case of photographic astrometry.

Now, if our telescope has a spectroscope attached, a truly amazing amount of information can be deduced from a single plate. The first thing we should note is the velocity of the star in the line of sight. It appears that about one fifth of the stars in the heavens are not single, but have companions in orbital motion. In this datum, we should be somewhat in error in one case in five if we had only one observation. While considering line-of-sight velocity, we might note that in the case of the more distant spiral nebulae the apparent radial velocity and the distance are related in such a manner that the distance can be found from the spectrum, by means of the red shift. Nearly all of the galaxies appear to be receding at rates depending on their distances.



The spectra of three pairs of stars of the same spectral type are shown here, but in each case the upper spectrum is that of a giant star, and the lower is that of a dwarf. Chi Aurigae and Alpha Cygni show sharper lines than the respective dwarfs of the same type. Below, the lines of ionized strontium in the giant, Zeta Capricorni, appear stronger than in our dwarf, G-type sun. So the different densities of giant and dwarf stars of the same spectral type are revealed by their spectra.

Further information can be learned from the top pair of spectra, where the appearance of interstellar calcium (Ca+) in the spectrum of Chi Aurigae shows its great distance compared to that of Eta Aurigae. The spectra are by W. W. Morgan, of the Yerkes Observatory.

Only a few stars show a variable spectrum; these are among those whose brightness is variable. The class of spectrum is very little variable for 90 per cent of the stars, so that a single observation tells us with great certainty the chemical constitution of the star's atmosphere, the state of excitation, and from this the temperature, and the relative brightness of the different parts of the spectrum. This brightness ratio also permits the determination of the temperature. Further, nearly all the known stars can be arranged in a spectral sequence, such that there is only an almost imperceptible difference between each star and the one most like it on either side; yet the range of spectral type is from the white or bluish stars, whose spectra show mainly non-metallic elements with hydrogen and the noble gases prominent, to the very red stars whose atmospheres contain the metals and even show the spectra of compounds.

The theoretical astrophysicists believe that the spectral sequence shows the progress of a very slow evolution, requiring trillions of years for a star to change from a white to a red one, or the reverse. Granting the validity of this theory, a single plate of a stellar spectrum, which we can imagine being made instantaneously, tells us not only the conditions of the star's atmosphere at the moment, but allows us to speculate with considerable certainty on the star's very remote past and equally distant future.

We have mentioned that nearly all stars fall into a spectral sequence. For instance, 100 stars may be classified as *M2*, and a fairly careful examination of a small-scale spectrum plate would show no difference between one of these spectra and any other one. Yet, if a proper pair of lines were chosen and accurate measurements made of the relative intensities of these lines in each of the 100 stars, considerable differences in this ratio would be found. The pairs of lines were originally chosen in a quite empirical manner; experience showed that this ratio for certain pairs of lines was a criterion of the star's real, or absolute, brightness. It has since been learned that in each case one of the lines refers to quite a different stage of excitation or ionization than does the other; so, without knowing it, the earlier observers were making observations of the star's ionization, which in turn is associated with surface brightness. Having estimated the star's absolute brightness (its apparent brightness at a standard distance), we refer to the first datum mentioned, the star's apparent brightness, and from the ratio of these two photometric data the distance of the star may be inferred. In fact, of all the information which we obtain concerning some 80 per cent of the individual stars, only the motions across the line of sight require more than one observation to establish each datum with some precision.

Now this seems to be quite a lot to learn about a star by collecting the stellar energy which is found in a cubic meter of space; yet we have treated the matter in the merest outline. If all the useful data which are obtainable from one plate of each star were published in quarto form, not more than 1,000 stars could be accommodated in a large volume, and the fact

(*Continued on page 15*)

BEGINNER'S PAGE

SPECTRA — II

Doppler, Zeeman, and Stark Effects

By Percy W. Witherell

LAST month we stated that "the positions and colors of these [spectral] lines are always the same for any one element radiating under the same conditions." The Doppler, Zeeman, and Stark effects are the results of changes in the radiating conditions, which in practice includes changes in the receiving apparatus, as well.

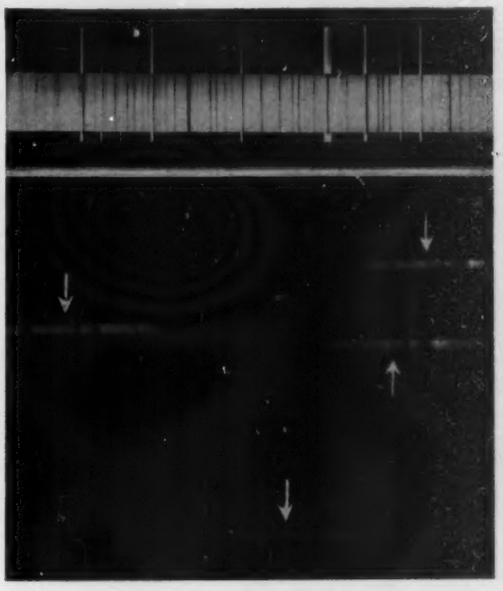
One of the most useful variations has led to many discoveries, and also to many mysteries that are yet to be explained. This is the *Doppler effect.* You may have noticed the sudden drop in the pitch of the bell on an approaching locomotive as the train passed you. This was caused by the fact that the approaching sound waves were crowded together by the motion of the locomotive, whereas when it went away from you they were spread out. In the first case, the original number of vibrations emitted by the bell is crowded into a shorter interval, raising the pitch above normal, and in the second, lowering it noticeably.

In a similar manner, the number of waves per unit of time passing through a spectroscope from any source is changed if the radiating body is approaching or receding from the spectroscope, or if the instrument is itself moving relative to the source. If the motion is that of approach, the spectrum and its lines appear shifted toward the violet (shorter waves), and if of recession, the shift is toward the red.

In the case of the stars, the Doppler effect is important in measuring their velocities along the line of sight, in determining some of them to be double, in determining their velocities of expansion and contraction, and their rotations, and for other reasons.

But in the spectral lines themselves, the motions of the radiating or emitting atoms cause broadening of the lines by the combination of innumerable Doppler effects. Some of the atoms are approaching, others receding, and others moving at various angles to the direction of the spectroscope. The light (or absorption) of one atom may therefore appear shifted slightly to the red, while that of another will be shifted toward the violet. The large numbers of atoms involved in producing a single spectral line are usually moving at random, and the line has its edges fainter than its central portions, in accordance with the law of probability. A graph of the intensity of the line looks like the curve seen in the apparatus that demonstrates the law of probability — shot that are dropped at the apex arrange themselves in a symmetrical figure on both sides of a rather sharp peak. The combined radiation may be likened to that of a radio transmitter, which, although assigned a definite frequency, has considerable output on either side of this frequency which represents the point of its maximum strength.

As the temperature of a gas rises, its spectral lines tend to be further broadened by this same Doppler effect. The average speed of the atoms increases with the temperature, so the difference in motion of those receding and those approaching is greater — the spectral lines appear broader than before. Lines of different elements are affected differently; for instance, hydrogen, the lightest gas, has the greatest average velocity of the gases in a given sample, and, therefore, the hydrogen lines show the most pronounced Doppler widening.



Two methods of determining the Doppler shift produced by a star's motion in the line of sight are shown here. At the top is a slit spectrogram compared with a bright-line laboratory spectrum of iron. Note the displaced position of the absorption lines of iron in the star's spectrum. The lower photograph shows several stellar spectra taken with an objective prism and a neodymium chloride filter. The latter produces the reference lines indicated by the arrows.

If the radiating atoms are involved in a magnetic field, there is a change in the atomic energy levels between which electrons jump when atoms radiate or absorb energy. The number of energy levels associated with a given line increases, and the line is broken into a number of components. These components are usually polarized, so they may be studied by placing polarizing apparatus in front of the spectroscope. It is in the light from sunspots that this *Zeeman effect* is most noticeable, thereby proving the existence of powerful magnetic fields in these solar cyclones.

Radiant energy is often called electromagnetic radiation, so it is not surprising to find that an electric field will alter the lines in the spectrum in a manner similar to the Zeeman effect. In the laboratory, the electric field impressed on a gas may be made very powerful when compared to the electric fields of the atoms themselves, and it may be made relatively constant. The resulting *Stark effect,* observed in laboratory spectra, is a splitting of the lines into fine components, but such splitting is not found in stellar spectra.

In stellar atmospheres, which give rise to the absorption lines in stellar spectra, there are a great many free electrons and atomic ions, possessed of positive and negative electric charges. The electric fields affecting an individual atom are, therefore, continually changing, with the result that the Stark effect does not produce separate components. There is only a blurring of the line, and it is this blurring which is so helpful in distinguishing dwarf stars from giants of the same spectral class. (See the spectra on page 8.)

Although originally named for their greater luminosity, giant stars actually occupy much larger volumes of space than do ordinary, or dwarf, stars, such as our sun. As the amount of matter a star may contain is rather limited, these larger stars do not have masses in proportion to their sizes — therefore they are of lower density than the dwarfs. This is particularly true of their atmospheres. Low density means that the atoms are spaced relatively far apart and the electric fields have comparatively little effect on each other, so here the spectral lines are broadened only slightly by the Stark effect.

In dwarf stars, however, the density is higher, the electric fields are closer to the radiating particles, and broad, fuzzy lines are produced, particularly for the elements hydrogen and helium. In spectra which appear otherwise nearly alike, narrow lines may indicate giant stars, and wide ones, dwarfs.

Soliloquy of a Variable Star Observer

By Cyrus F. Fernald

IT WAS seeing conditions which led me to observe variable stars, in preference to other astronomical work. I have found that variable star observing can be done with seeing conditions under which an observer cannot do anything else. In fact, it may be a little easier to make estimates when the air is so disturbed that the star images are abnormally large. The same effect can be secured by throwing the eyepiece slightly out of focus, as is the recommended procedure in estimating comets.

Concerning my local (Wilton, Me.) seeing conditions, in my 10 years' observing (say, 2,000 hours), I have seen one night when for about two hours the seeing was extremely good. For that brief period I could separate double stars down to the Dawes limit. There have been a few other occasions when I could approach that limit, but I consider myself lucky to have one or two of these a year.

Under such conditions, it isn't logical to attempt drawing planetary or lunar detail, or trying to measure close double stars.

My telescope is mounted out-of-doors on a stone pier. Nearby I have an automobile trunk in which I keep mirrors, eyepieces, notebooks, and other accessories. Also I have a writing table with a red light. Under the conditions prevailing on 90 to 95 per cent of the nights on which I work, an observatory would be a nuisance. During the few nights when I would like one, I console myself with the knowledge that the seeing is probably terrible, because of the wind.

I have more than one mirror in use. There is the regular mirror for work with variables and other night objects. Then I have a plain, unaluminized mirror for use on the sun, that I combine with a solar prism and proper dark glasses to observe sunspots.

My Springfield-mounted telescope has an 8-inch mirror of 75 inches focal length. The optical system includes a 2-inch prism and a 1½-inch prism. For most variable star work only two eyepieces are used, a 2-inch Ramsden, with a field of view of about one degree, which makes identification of the field easy, and a ¾-inch Kellner, which has a field of just over half a degree. The 2-inch will show stars between the 11th and 12th magnitudes under reasonable conditions; the ¾-inch will get down into the low 13's and occasionally hit the 14th.

I do not use a finder for locating variable stars. The adjustment of my telescope is good enough so that I can locate the fields quickly by using the setting circles.

In the Springfield mount the finder's eyepiece is in an inconvenient location, and it seems to me that trying to use a finder with it would be very unsatisfactory. With a refractor or Newtonian form of reflector, the finder's location makes its use advisable, for in these cases it may be the circles that are inconveniently located.

For reading charts and recording observations, I have an old automobile spotlight with a 7½-watt red bulb connected to the regular 110-volt lighting circuit. A sheet or two of red wrapping paper tones the light down to just the right intensity to read charts easily, while not unduly affecting the observer's eyes. As this light is not movable, it is necessary to use a small single-cell flashlight for reading the setting circles. A sheet of red wrapping paper is needed here also.

Fairly frequently, I am bothered by condensation on the optical surfaces. I have found that a small heating element fixed so that it will warm the metal prism holders slightly is sufficient to remove dew and frost. The local power company uses these heaters to warm meters placed in exposed positions. They cost 30 to 50 cents, pre-war prices. Their use increases my observing time by about 15 per cent.

For observing variables, I use the B, C, and D charts furnished by the A.A.V.S.O. The B charts are for locating the variables, and are satisfactory for estimating their brightnesses when they are above the 11th magnitude. The C charts issued since 1940 are among the best available. For the field of view obtained with the 2-inch eyepiece, with my mirror, these charts are ideal, for they cover enough field to make location easy, and show faint enough stars so that reference to the D charts is seldem necessary. The earlier C charts do not show all the stars in the field of view, and this is often very confusing. The D charts are needed when the variable is fainter than the 11th or 12th magnitude, to check the faint stars in the field, and to make sure of the location of the variable. Where the field is congested, the still larger-scale E charts are useful, but for as small a telescope as mine I wouldn't advise them.

Observations of any regular variable are made at 10-day or longer intervals. As I understand it, all the observations of the regular variables are ledgered and used as 10-day means. There would seem to be little point in any one observer checking these stars oftener than once in 10 days.

The rapidly varying irregulars of the

The author finds that most of the time "an observatory would be a nuisance." Note the automobile trunk, and other conveniences.

Ed. Note: The author writes us that a good deal of the material in this article was prepared some months ago when he expected the Army to terminate his variable-star and other activities for some time (he was later turned down because of bad eyesight!), and that it was prepared with the idea of furnishing him with a basis on which to start again when the "present unpleasantness has been liquidated." He modestly does not mention that for the past two years he has led all members of the A.A.V.S.O. in the number of observations submitted, and is so familiar with the star fields as to average about 20 stars an hour.

SS Cygni and Z Camelopardalis types should be checked every night that observing is possible. In fact, occasionally I observe them in the evening and morning of the same night. On the bi-monthly prediction sheets furnished by the A.A.V.S.O., these stars are indicated by **.

Frequently it happens that the association is particularly anxious to get observations of a regular variable that needs attention. These carry a * in the bi-monthly sheet. To make sure of these, I check them every five to 10 days, not waiting for the full 10-day period. R Coronae Borealis stars, and RV Tauri stars, also, may be checked every five days without wasting the observer's efforts.

Each of my observations is recorded three times, first on what may be called "the observing record sheet." For these I rule the backs of old letters in 3/8-inch squares. With dates on the *x* axis and stars on the *y* axis, one sheet serves 25 regular variables for six months or more. One sheet a month for the irregulars and specials is needed. A dozen or so sheets take care of all the stars I observe. These are temporary records. As soon as is convenient, the data are transferred to my permanent record sheets, one for each star. These sheets are ruled to give three items for each observation: Julian day and fraction; brightness of the variable; check of the observation against others reported in the Harvard *Annals* for the same date. One sheet serves for about 200 observations, enough for 10 years' work on a regular variable, or two years for an irregular. From these permanent record sheets, I make out the monthly reports for transmission to Harvard College Observatory.

I presume the first two recordings could be consolidated, but the slight gain in observing time and convenience given by the present method offsets the time spent the next day in making transfers from the observing record to the permanent one.

While observing, I include other phenomena besides variable stars. Usually, I check one or two nova-search areas every week or so. I suppose this should be done more frequently, and in a casual manner I do it every night that I observe, but a full, complete verification down to the 6th magnitude once a week is enough for me. I use 6x binoculars, with a field of five degrees.

All meteors noted while I am observing are reported on forms furnished by the American Meteor Society, whose director, Dr. Charles P. Olivier, of the University of Pennsylvania, seems most appreciative of such reports. The time involved in making a record of a meteor is no more than that required for recording a variable star observation. As a rough average, I see one meteor for each two and a half hours' observing time.

Any displays of aurorae are reported to Cornell University, to assist in the program of research Dr. C. W. Gartlein is conducting in conjunction with the National Geographic Society.

Certainly, there is permanent value to variable star observing. The very meager records of the Chinese of 1,000 to 2,500 years ago are of great interest to us now, and we may hope that the information we get in our day will be of value to those who may eventually succeed in finding out the complete story of these interesting stars. To contribute, even a little, in helping to solve the problem, is the reward of the variable star observer.

Amateur Astronomers

A NEIGHBORLY FIELD TRIP

MORE than 50 members of the New York Amateur Astronomers Association and the Bergen County Astronomical Society got together on Saturday, July 3rd, for a joint rally at the Teaneck, N. J., observatory of the latter organization. Thirty-two members of the A.A.A. made the bus trip from New York; for them it was a special field trip which avoided wartime travel restrictions.

The first session got under way at 5 p.m. with a word of welcome by Edward Hopkins, president of the B.C.A.S., who introduced George V. Plachy, secretary of the A.A.A. Mr. Plachy described various methods of sundial construction. To be accurate, a permanent dial must be laid out especially for the locality in which it is to be used. At the close of his talk, Mr. Plachy presented to the Teaneck group a dial designed for the position of its observatory.

At 6:30, the group adjourned to the home of Anthony Frey, in the West Englewood section of Teaneck, for a picnic supper amid a grove of trees, returning to the observatory at 8 o'clock. By this time Venus was in fine position for observing, and its disk, a little less than half full, was a glorious sight through the 12-inch telescope.

After everyone had had a good look, the crowd assembled in the lecture room for a talk on the history of astronomy by Marinus Rose, who showed many fine lantern slides to illustrate his points.

Meanwhile, the sky became completely dark, and more observations were in order. The Hercules cluster, the Ring nebula, Albireo, Mizar, and other objects were viewed, and two 6-inch instruments, brought to the observatory by President Hopkins and Clarence Johnson, of the B.C.A.S., were also kept busy. Finally, Mr. Plachy showed a set of handsome colored slides, and the meeting disbanded shortly before midnight.

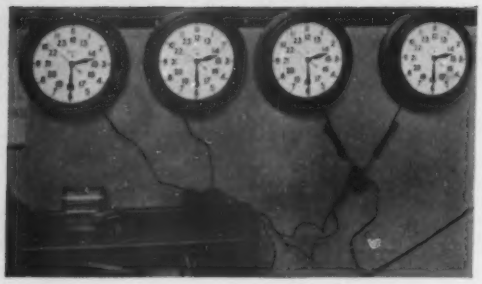
The Bergen County society had its inception 10 years ago, and most of its activities have revolved around the fine 12-inch Newtonian reflector built in 1936-37 by Frank J. Wanderer and other members, and now used under a continuing agreement between Mr. Wanderer and the society. The mirror has a focal length of 95 inches — virtually f/8; the 'scope is electrically driven and equipped with setting circles. The tube can be rotated to insure comfortable observations, and it is equipped with a turret adapter by means of which eyepieces of different power can be put into use with a minimum of effort.

The observatory, situated on the ground of the Teaneck High School, consists of two parts. The observatory proper, housing the telescope, is 16 feet square, has a sliding roof and an observing platform. The lecture room, fully insulated and heated in cold weather, is equipped with a blackboard and other accessories. Here also is a splendid seismograph built by Mr. Wanderer, which the group hopes to put into operation in a vault to be constructed after the war.

Although its activities have necessarily been curtailed by the war, the B.C.A.S. is continuing a program initiated several years ago, designed to popularize the study of the stars. Groups of school students, Boy and Girl Scouts, clubs, and church organizations assemble from time to time at the observatory for a short talk, followed by use of the telescope. In addition, the observatory is open to the public every clear Friday night throughout the year. Visitors from New York should take the bus at George Washington Bridge Plaza to Teaneck High School, at Route 4 and Margaret Street.

The field trip committee which arranged the July 3rd gathering for the A.A.A. consisted of Jane Davis, chairman, Hazel Boyd, Antoinette Finocchi, Peter A. Leavens, Marion Louis, Charlotte Malsbary, Helen O'Connor, Harry Stringer, and Mr. Plachy (ex-officio). Arrangements for the B.C.A.S. were in the hands of R. S. Dodson, Jr., Ruth Frey, Mr. Wanderer, Mr. Hopkins (ex-officio), and the undersigned.

J. M. STOFAN
corresponding secretary
Bergen County Astronomical Society



These observatory clocks tell sidereal time, gaining nearly four minutes each day over ordinary timepieces.

THE ANSWER'S IN T

By William H. Barton, Jr.

The answers to many perplexing questions about motions and pp with a knowledge of the sky, as told here and in the Hand Pl

WHAT time is it? What's the time in Attu? What is the date? Is it hot because we are nearer the sun than we were at Christmas? Why is there a midnight sun? How can I tell what time it is without a watch? How can I find my directions without a compass? To these questions and many others we can say: The answer's in the sky.

On the sky, man found the original clock and calendar. And the motion of the heavens is still fundamental in timekeeping today. It is really the earth that is the timepiece, but appearances make the sky the moving clockface on which the numbers—stars—are marked. The hand is the meridian. Unlike other clocks, the face moves while the hand is stationary. Every time the earth spins around, the meridian sweeps across the star fields back to its original place at the end of 24 sidereal hours. To be sure, the meridian is always above us, running from north to south through the point overhead. Therefore, it is the stars that appear to move across the meridian, marking star time or *sidereal* time, the most fundamental of all. Every clear night astronomers at the United States Naval Observatory make observations of star transits across their meridian, and check their master clocks.

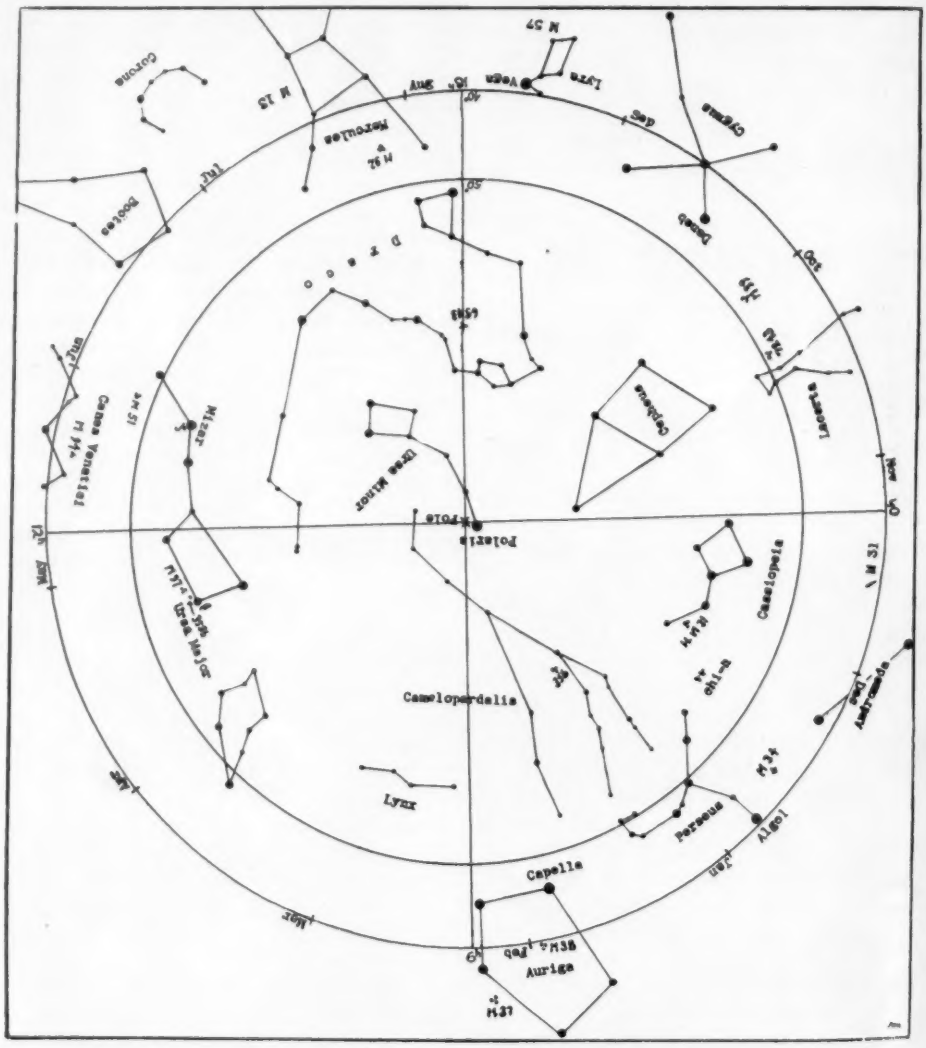
But we also measure time by the sun. When the sun reaches its highest altitude each day, it is exactly south to us here in the Northern Hemisphere. A simple sundial, properly oriented, then reads noon—local apparent noon. This kind of time is called *apparent solar*.

Sidereal and solar time are not alike. The sun does not remain fixed among the stars, because the earth, in its yearly trip around the sun, occupies a different position in its orbit each day. As a result, the sun appears to move slowly eastward among the stars. This motion delays the sun's passage across the meridian compared to the stars', and the solar day becomes longer than the sidereal day by several minutes. However, because the earth does not have a uniform speed around the sun, that body does not change its apparent place by an equal amount each day, so the solar days are not uniform in length.

Most timepieces run uniformly (or are designed with that function in view) and therefore do not follow the real sun in the sky. For their especial benefit, astronomers have created a fictitious sun that does run uniformly and thus averages out the irregularities in the real sun's motion. This imaginary object is the *mean sun* and is the basis of *mean solar* time, or "clock time," as it is often called.

These are the basic kinds of time, and their determination depends finally on observations of the sky. The answer's in the sky, if you can but read it there. In our jungle and desert warfare, the boys are finding it necessary to know how to find their directions and tell time by the sun and stars. There are portable sundials and star clocks. Generally people are better at "guessing" the time by the sun than by the stars. But you can get your approximate time from the Big Dipper. The method is described by Dr. C. C. Wylie in *Our Starland*. Try it and learn to tell time by the stars:

If you look toward the north, you will find the Big Dipper and Polaris, the North Star. Imagine Polaris to be the center of a clockface and the Pointers (by which you probably found the North Star) to be the hour hand of the clock. "Read" this clock to the nearest quarter hour. That is, imagine the clock to be on your mantelpiece at home and judge the time from the hour hand alone. You probably will not do very well at first—the trick needs practice. Suppose this sky clock reads 8 o'clock (that is, the Pointers form an



The Big Dipper furnishes us with a watch of moderate accuracy, when we learn to read it. It is shockproof, but unfortunately not waterproof. The dates indicate the upper meridian at 10 p.m. war time. Drawing by H. S. Rice.

THE SKY

ppearances can be found Planetarium this month.

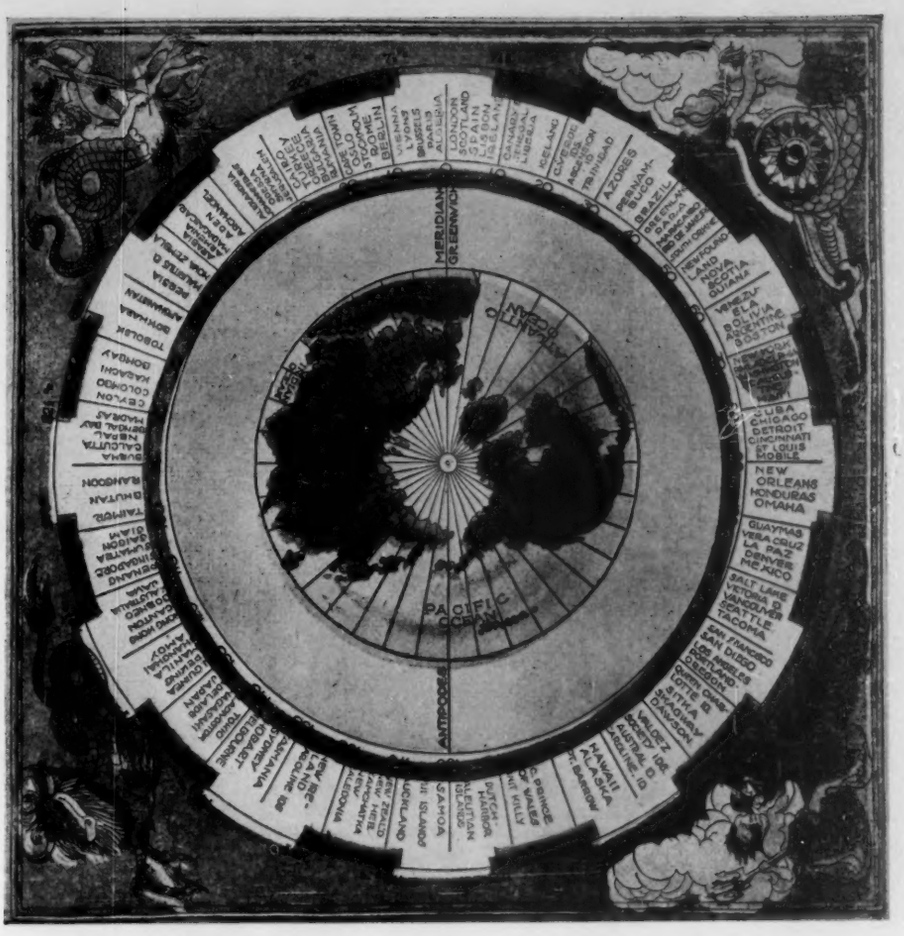
angle of 60 degrees to the west of the meridian below the pole).

That is all the observation required. The rest is simple arithmetic. Add to 8 the number of months and quarter months since New Year's Day. August 15th would be 7½ months. The sum is 15½. Double this, making 31. Subtract 31 from 16¼ (or 40¼, adding 24 to make the subtraction possible). The result is 9¼. This is the number of hours since noon, and the time is 9:15 p.m. The result, of course, is *local* time, and if you want standard time, you have to correct for the difference between your longitude and that of the standard meridian for your standard-time zone.

Our calendar, too, is ruled by the sky. The civil calendar is solar in its origin, although our religious calendars are generally lunar. Everyone is familiar with the sun's apparent traveling north and south during the seasons, and with the day and night being of equal length at the equinoxes. The year once began when spring began, but no matter when the year starts, it must have a length that represents the time the earth takes to go once around the sun from equinox back to the same equinox again, or the calendar will get out of step with the seasons.

That actually happened to the old Julian calendar, and gave rise to the Gregorian calendar that we use today. Julius Caesar, in his calendar reform, had decreed 365¼ days as the length of the year. Common years were to have 365 days and every fourth year was to be a leap year. The fact is that the tropical year is not 365 days and 6 hours in length, but only 365 days, 5 hours, 48 minutes, and 46 seconds. Caesar was wrong by 11 minutes! It seems like a small discrepancy, but in three years it represents more than half an hour and in 150 years it is about a day. By the latter part of the 16th century, the calendar was about 10 days behind the seasons. It was this that induced the church authorities to devise a new calendar, with the principal difference being the omission of leap years in century years not divisible by four.

There are still people who thoughtlessly believe that we have hot weather when we are near the sun and cold weather when we are farther away from the sun. This year the earth was at perihelion (nearest the sun) on January 2nd, when it was 91,447,000 miles distant. We were at aphelion on July 4th, 94,556,000 miles away. In the Southern Hemisphere, of course, they *were* having summer in January and they had winter in July, so the statement holds true there, but the reason is different.



Around the world, places in different latitudes but in the same longitude from Greenwich are keeping the same standard time.

For the seasons are caused not by this three-million-mile difference in distance (only three per cent of the whole) but by the changing inclination of the sun's rays as they strike various parts of the earth. Between March and September the sun is north of the earth's equator; on March 21st it is exactly overhead along the equator, and each day thereafter it creeps a little northward. By June 22nd, the sun is overhead along the Tropic of Cancer, 23½ degrees north latitude. The Northern Hemisphere is more directly under the sun than the Southern.

The sun is then so far north that it shines across the north pole and illuminates a region 23½ degrees beyond the pole. On the other hand, the solar rays cannot reach the south polar regions; in fact, they cannot get within 23½ degrees of the south pole. Thus are marked out on the earth the Arctic and Antarctic Circles, the limits of a six-month day and a six-month night.

The Tropic of Cancer marks the limit where the sun can shine overhead in the Northern Hemisphere. After June 22nd, the sun starts its southward journey. By September 23rd, it is again "crossing the line," and by December 22nd is over the Tropic of Capricorn, and the conditions are reversed.

The answer to the question of the seasons' cause, therefore, is in the sky, too. Those terms, Tropic of Cancer and Tropic of Capricorn, come from the sky. Before the precession of the equinoxes moved the summer solstice into Gemini, it was in the constellation of Cancer, the Crab. The winter solstice, now in Sagittarius, was once in Capricornus. (See "The Obsolete Tropic of Cancer," *Sky and Telescope*, July, 1943.)

The tilting of the earth's axis to its path around the sun is the cause of the shifting of the sun's apparent position through the seasons, and of the midnight sun.

There is another way to think of the midnight sun. Suppose you were standing at the north pole of the earth during the winter. Exactly overhead you would find the north celestial pole and very near it, Polaris, the North Star. You could see half the sky from that point, and only half. The half south of the celestial equator would be below your horizon. The horizon would cut the celestial sphere into two halves, one visible, the other invisible. As the earth

ASTRONOMICAL ANECDOTES

PHOTOGRAPHS — LATEST AND EARLIEST

FOR the past five months, this department has been concerned with old star catalogues and atlases. I believe the time has now come to leave this discussion, at least for the present, and to collect some odds and ends.

As a sample, more than a year ago there were some notes here having to do with the visibility of stars by day. Now we can speak of the photography of stars by day.

Many photographs of Venus, Mercury, and even of a comet, have been made by day, without the darkening due to an eclipse. But the use of a coronagraph has made possible a most remarkable feat, according to reports from Europe. The British journal, *Observatory*, condenses from *Zeitschrift für Astrophysik* the accounts of the work of M. Waldmeier, who has a coronagraph atop Mt. Arosa.

At 11h 30m U.T., August 22, 1941, Waldmeier photographed Regulus, a star whose magnitude is 1.34. If this seems somewhat short of remarkable, take a look at an *American Ephemeris* for that year, and find the sun's coordinates for that date and time, and compare them with the position of Regulus. The star was then only 12 minutes of arc, or less than a solar radius, from the limb of the sun!

At Waldmeier's station, where the altitude is 6,725 feet, the scattered sunlight at 12 minutes of arc from the sun's limb on a clear day is about one fifth as bright as Regulus. Waldmeier used a red filter (passing only wave lengths longer than 6200 A.), and this served to increase the contrast. But even in the best optical systems there are sources of ghosts and other parasitic light, and in order to "smear out" their images, the field lens of the coronagraph was rotated about its optical axis at a rate of three revolutions per second. In a 15-second exposure, the image of Regulus came out quite well.

Several years ago, Dr. Keivin Burns suggested that as a result of certain new emulsions becoming available, interested amateurs could photograph deep-red variables by day. But this recent development has one very special application in the leisurely redetermination of the amount of the deflection of starlight at the sun's limb, to check predictions of the theory of relativity. Such observations heretofore have been made during total solar eclipses, and many people have voiced the objection that the conditions of refraction at the edge of the moon's shadow cone may vitiate precise astrometry at such a time. This new method will not be subject to such a complaint, but there must be devised a sound theory of measurement of the coronagraph pictures, for the optical systems of such instruments, in order to preserve a maximum amount of unscattered light, are not highly corrected.

Exactly two years ago, mention was made here of a photograph on glass made by Sir John Herschel. Now I can set down something more, supplied by Miss E. Wadsworth, the new assistant secretary of the Royal Astronomical Society, who seems to be as energetically helpful as her predecessor, Miss Williams. Miss Wadsworth has written down for me the legend accompanying the copy of the photograph in question which hangs in the society's rooms. I shall save the complete text for the time when I can reproduce here the photograph itself.

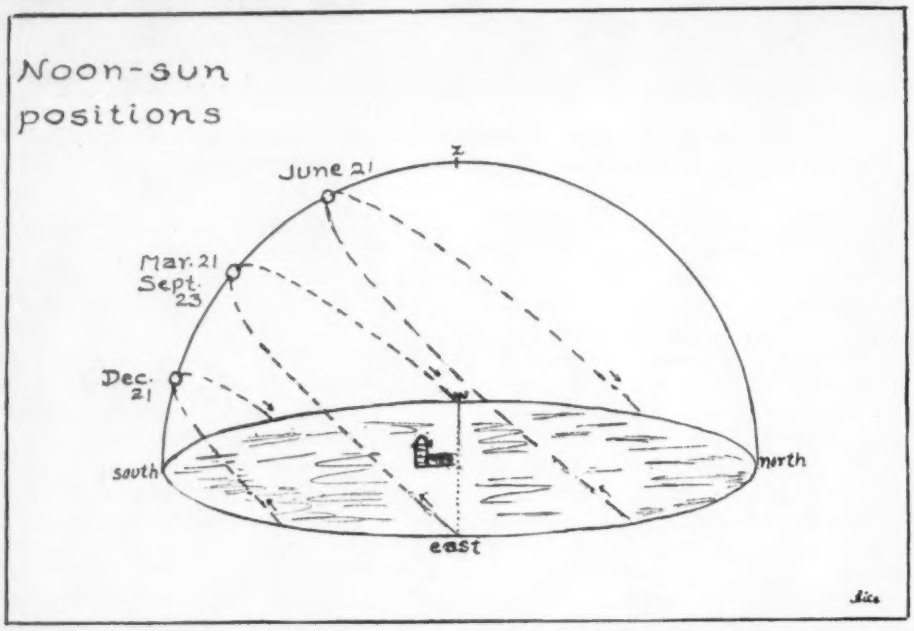
The method of making and sensitizing the plates may be described now, however. A glass plate, under water, received a deposit of "muriate" (chloride) of silver from a mixed solution of silver nitrate and common salt. After 48 hours, the chloride had formed a film firm enough to bear draining off the water by means of a siphon. When it was dry, the film was very little affected by light, but when it was washed with a weak solution of nitrate of silver, then dried, it became very sensitive.

The plate was exposed in the camera with the glass toward the incident light. The image was "fixed" with the familiar hypo, which John Herschel had suggested for such use 20 years earlier. The resulting photographs were the first ever made on glass, and John Herschel called them "negatives." From them, he printed a few "positives," but these have become lost.

The most interesting of the negatives is preserved in the South Kensington Science Museum, and from it, in August, 1890, 25 copies were printed, natural size, by projection. It shows the great reflector of Sir William Herschel, with the 40-foot tube lowered for the last time. The whole structure was dismantled in December, 1839, so this photograph was made before that time.

The important event apparently is not mentioned in histories of photography.

R. K. M.



In temperate zones, the length of the day and the maximum altitude of the sun change together, combining their effects to produce the great variation of temperature with the seasons.

spins, the stars would not rise nor set, but would swing around parallel to the horizon. Half the sky would be circumpolar. And the sun would not rise during the winter.

On March 21st, the sun reaches the equator and you would see it on the horizon, skimming completely around it each 24 hours. Every day it would move nearly parallel to the horizon, but slightly higher on succeeding days —really a slow, spiraling motion. By June 22nd, it would have reached its highest altitude of 23½ degrees, and by September it would again have spiraled back to the horizon. As long as the sun remained north of the equator you could see it, and as soon as it moved south of the equator you could not. If you were to zip down to the south pole as the sun disappeared from your view up north, you would see it just above the horizon from your observation point down there, and for the succeeding six months the southernmost part of our world would be favored with the midnight sun.

There are many of these puzzling questions, but to every one of them— the answer's in the sky.

NEWS NOTES

By Dorrit Hoffleit

ENEMY STAR?

Excitement must surely have been high in Germany when a comparatively stationary light was being shot at in the expectation that it was an R.A.F. attacking plane. The *Journal* of the British Astronomical Association reports R.A.F. pilots as telling that considerable ammunition is expended on Sirius, "the most shot-at star."

LARGEST PRISM

The biggest prism ever made has been successfully cast by the Bausch and Lomb Optical Company in Rochester. It is to be used with the Schmidt-type Burrell telescope of the Warner and Swasey Observatory of the Case School of Applied Science at Cleveland. The prism, 26 inches in diameter and weighing 260 pounds, is graduated in thickness from 1.5 to 3.25 inches.

The Burrell telescope, made up of a 24-inch lens and a 36-inch mirror, has a wide field and high speed for photographing faint or distant stars. When the prism is added, the instrument will be used in the photography of spectra which will help solve mysteries on the nature of starlight, stellar temperatures, and radial velocities.

PHOSPHORUS IN THE SUN

The Indian journal, *Science and Culture,* for April, 1943, just received, contains a report by K. Narahari Rao, of the Solar Physics Observatory at Kodaikanal, on the presence of the phosphorus molecule in the solar atmosphere. Rao had previously analyzed the laboratory spectrum of this molecule in the region near wave length 2800 angstroms. Knowing that a large number of faint lines in the solar spectrum in this region had not yet been identified, he compared their wave lengths with his laboratory results. From the number of coincidences, he concludes that the phosphorus molecule is present in the atmosphere of the sun. "This conclusion," he says, "is supported from physical considerations as well. The P_2 molecule is stable enough for the temperature existing in the solar atmosphere."

PEARCE'S NEW DOUBLE STAR

Last month you read (in "American Astronomers Report") about Dr. J. A. Pearce's discovery that the 8th-magnitude star in Auriga, HD 34333, is a double with a period of revolution of a little over four days. Dr. Pearce predicted that it might also be an eclipsing binary with a variation in the brightness of the combined light of probably 0.05 magnitude. Dr. S. Gaposchkin, intrigued by this possibility, examined the star on Harvard patrol photographs, and found a variation of 0.29 magnitude from 1,082 observations. Besides the primary minimum, the light curve shows a well-defined secondary minimum 0.11 magnitude fainter than maximum.

From his photographic observations, Dr. Gaposchkin obtains values for the masses of the two component stars of 26.7 and 26.6 solar masses, in good agreement with the masses 23.2 and 23.1 deduced by Dr. Pearce from his 49 spectroscopic observations.

AN OLD NOVA

To the average layman and amateur astronomer, a nova is an exciting star only so long as it remains bright enough to be easily seen with the naked eye or low power. Astronomers who keep an eye on such stars after the glamour stage of stellar luminosity is well past are sometimes rewarded with further excitement. Thus, Dr. R. Minkowski, at Mt. Wilson Observatory, has found some interesting developments in the recent history of T Coronae Borealis, a nova of 1866.

T Coronae Borealis has been believed to be a binary star consisting of a red giant and a blue variable star — the old nova. Comparing spectra of this blue star taken in February, 1943, with one taken in May, 1942, Dr. Minkowski finds evidence for the formation of a stationary shell of gas around the star. Stationary shells have hitherto been observed in some hot, early-type (blue) stars, but this is the first instance on record of a nova having developed this particular kind of shell. The development was accompanied by an increase in the star's brightness.

OUR COOLING PLANET AND THE ORIGINAL LOCATION OF LIFE

According to Science Service, Dr. Perlet G. Nutting, of the U. S. Geological Survey, has worked out a probable sequence of events occurring while a mass of hot vapor torn from the sun by a passing star cooled into the planet Earth. Starting with dense vapors at a temperature of about 5,000 degrees centigrade, the liquid core would have formed at about 4,000 degrees, the first solids at 3,000 to 2,500, and silica and silicates at 1,500 or less. As the temperature fell below 374 degrees C., some of the water vapor condensed into water; and as it decreased further, with all the oceans boiling and copious rains of hot water, all but the most soluble of the rocks that had been formed were rapidly being eroded and redeposited. Living matter could have begun only during the very recent thermal history of the earth when temperatures were not greater than 50 degrees (122 degrees Fahrenheit). At about that temperature, the thick upper atmosphere probably began to thin out, permitting the polar regions to cool before the equatorial. Since temperatures compatible with life were reached in the polar regions first, Dr. Nutting thinks it probable that primitive life originated there.

A REMARKABLE LIBRARY

(*Continued from page 8*)

that so many stars could be treated in so small a space is true only because the great majority of them can be collected into relatively few catagories, permitting the use of tables and other shorthand devices in their description. When we remember that only a small range of spectrum has as yet been studied for most stars, and that high dispersion is yet to be applied to nearly all of them, we may imagine that far fewer stars could be fully described in each quarto volume if we knew all that we shall know some day.

Let us consider a cubic meter of space situated far from any material body that might cast a shadow upon it. If we point our telescope through this restricted space in some direction we are able to get a picture of a star; and since we are postulating very great speed for our plates, we shall use only the energy in the cubic meter. Another telescope using the energy passing through the cube in some other direction would find out all the possible things about some other star. For through this cube the light of all stars is passing all the time, and the energy from one star has not to date been found to influence in any way the energy from any other. This cube, then, at all times contains a record of the velocities, distances, magnitudes, temperatures, constituents, and atomic or molecular stages of the elements, the present states and the past and future of many million stars. The publication, for all of these stars, of the sort of data which we have collected for only a few, not to mention the data that improved instruments will some day reveal, would require 50,000 quarto volumes—quite a library.

Yet, throughout interstellar space this information is contained in each cubic meter, or cubic centimeter for that matter. It is stored in a space smaller than the librarian's desk, or even as small as his paperweight. This is a goal for the microfilm process. And our theories of the nature of light and the manner of its transmission must take account of the infinite detail possible in space.

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Designing an Achromatic Objective—VII

(Continued from the June issue)

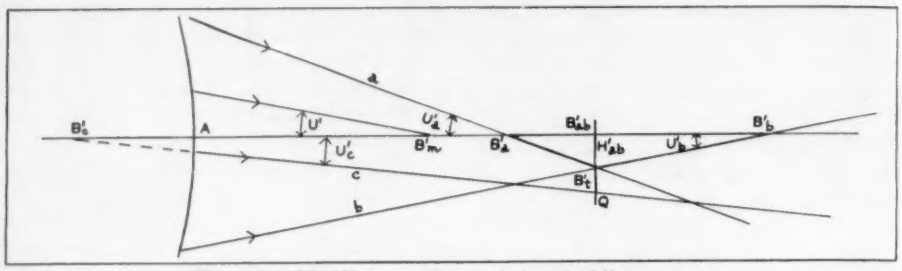

Fig. 13. The intersection points of oblique rays.

14. Interpretations.

a. Curvature of the field: Now, if L'_{ab} differs from L' of the axial pencil, the difference is curvature of the field. Hence we define:

$$\text{Curvature of the field} = L'_{ab} - L',$$

in which a positive value indicates the field is convex to the lens, that is, a "hollow" field.

b. Coma: The difference B'_tQ in Figure 13 is coma—the distance of the principal ray from the intersection of the two marginal rays **a** and **b**. This value is obviously:

$$\text{Coma} = (L'_c - L'_{ab}) \tan U'_c - H'_{ab},$$

the signs being chosen to make $B'_{ab}Q$ come out negative, as H'_{ab} is negative.

c. Distortion: This may be defined as the difference between the height (H'_c) at which the chief ray cuts the focal plane and the ideal height, which is: Ideal $H' = -f \tan U_c$, where f is the focal length of the lens, that is, $f = y/u'$ for the paraxial rays. In our case, $y = 3''$, and u' (from Table VI) = .032971.

Now, $H'_c = (L'_c - l') \tan U'_c$; hence,
Distortion $= -f \tan U_c - (L'_c - l') \tan U'_c$.

d. Sign conventions: The reader should take special note of the algebraic signs in the above work and of the direction in which algebraic differences have been taken in the various equations. One of the most prolific sources of trouble in optical calculations is in the algebraic signs. Drawing a careful scale diagram will often prevent many errors in sign.

15. The Results: Table VIII shows the preliminary closing equations, and Table IX the calculations for the aberrations themselves. The results are as follows:

Curvature of field	−.040″
Coma	−.002″
Distortion	+.001″

The tolerance permitted by the Rayleigh limit is .004″/tan U′ = .121″, so that all are well within the tolerance.

16. Astigmatism. Astigmatism presents a different problem. It cannot be determined by ray tracing by the fundamental equations, but requires a separate technique.

Consider a narrow incident bundle of oblique rays of paraxial dimensions. If we divide the bundle into two planes, one including the chief ray and the optical axis, and one perpendicular thereto, we find that these two flat fans of rays come to a focus on the central ray at different points. The distance between these two focal points is defined as the astigmatism.

Table VIII

PRELIMINARY CLOSING EQUATIONS

U'_a	2°25'19"	log $(L'_b - L'_a)$	1.74555
$-U'_b$	+1-21-29	+log sin U'_a	8.62591
$U'_a - U'_b$	3-46-48	+log sin U'_b	8.37475n
		log A	8.74021n
L'_b	125.883	−log sin $(U'_a - U'_b)$	8.81905
$-L'_a$	-70.222	log H'ab	9.92716n
$L'_b - L'_a$	55.661	H'ab	-.8456
L'_c	-0.822	log $(L'_b - L'_a)$	1.74555
$-l'$	-90.249	+log sin U'_b	8.37475n
$L'_c - l'$	-91.071	+log cos U'_a	9.99961
		log B	0.11991n
L'_a	70.222	−log sin $(U'_a - U'_b)$	8.81905
$-C$	+19.992	log C	1.30086n
L'_{ab}	90.214	C	-19.992
L'_c	-0.822		
$-L'_{ab}$	-90.214		
$L'_c - L'_{ab}$	-91.036		
log y	0.47712		
−log u'	8.51813		
log f	1.95899		
f	90.989		

17. Tangential Rays. The plane which includes the optical axis is known as the tangential plane. Let PB (Figure 14) be the chief ray of such a bundle as was described in Section **16**, incident at P on a given surface. B_o is the point on this ray which represents either the original object-point or the focus from preceding surfaces. The surface in question will refract the ray into the position PB′. Now let B_t P_t be another ray in the tangential plane, close to PB. This ray obviously meets PB in B_o, since B_o is the image or object point, and will be refracted into the position $P_t B'_t$, meeting PB′ in B'_o. The points B_o, B'_o will be defined by their distances from the surface *along the chief ray*, that is, by $PB_o = t$; $PB'_o = t'$. Let the angles be **U** and **I** for

Table IX

CLOSING EQUATIONS

L'_{ab}	90.214	log f	1.95899
$-L'$	-90.254	+log tan U_c	7.96889
Curvature	-.040	log f tan U_c	9.92788
		f tan U_c	.8470
log $(L'_c - L'_{ab}$	1.95921n		
+log tan U'_c	7.96889	log $(L'_c - l')$	1.95938n
log D	9.92810n	+log tan U'_c	7.96889
D	-.8474	log $(L'_c - l')$ tan U'_c	9.92827n
$-H'_{ab}$	+.8456	$(L'_c - l')$ tan U'_c	-.8478
Coma	-.0018		
		-f tan U_c	-.8470
		$-(L'_c - l')$ tan U'_c	.8478
		Distortion	.0008

EDITED BY EARLE B. BROWN

the chief ray, and U + dU and I + dI for the close tangential ray.

If the angle at the center (angle PCA) be called O, then the angle P_tCA will be O + dO, and U + I + dO = U + dU + I + dI, or dO = dU + dI.

Now, if we take P_t indefinitely close to P, we can write PP_t = r dO. Drawing PQ perpendicular to PB, we have: angle QPP_t = I, its sides being perpendicular to PB and PC, and therefore PQ = PP_t cos I = r cos I dO. But we also have PQ = t dU, where t is PB_o, and equating the two values of PQ gives us t dU = r cos I dO.

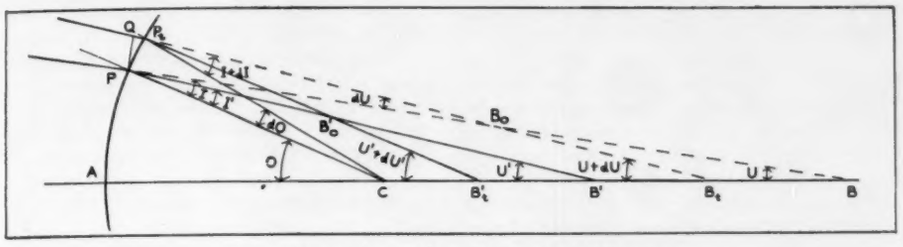

Fig. 14. Astigmatism of tangential rays.

We can replace dU by dO − dI, giving t dO − t dI = r cos I dO, and, solving for dI, we have

$$dI = \frac{t - r\cos I}{t}\,dO.$$

Now, obviously, we have the same situation for the refracted rays, namely

$$dI' = \frac{t' - r\cos I'}{t'}\,dO.$$

To relate these two we need only note that I + dI and I′ + dI′ are the angles of incidence and refraction for the tangential ray, hence they must be related by the law of refraction: N sin I = N′ sin I′. If we differentiate this, we obtain N cos I dI = N′ cos I′ dI′. Putting the expressions for dI and dI′ in this, we obtain

$$N\cos I\,\frac{t - r\cos I}{t}\,dO = N'\cos I'\,\frac{t' - r\cos I'}{t'}\,dO,$$

which can be transformed into a solution for t′, yielding

$$t' = \frac{N'\cos^2 I'}{\frac{N'\cos I'}{r} - \frac{N\cos I}{r} + \frac{N\cos^2 I}{t}}.$$

18. Sagittal Rays. We now turn our attention to the sagittal rays, or rays in the plane perpendicular to the tangential plane. The chief ray is common to both the tangential and the sagittal planes, so we have (Figure 15) the points A, P, C, B, B′, and B_o with the same meaning as before. We now draw an auxiliary optical axis through C and B_o, and let fall the perpendicular from P meeting the auxiliary axis at Q, and add the end-view as seen from B_o (at the left in the diagram).

Now, with respect to the auxiliary axis, PB (or PB′) is an axial ray, and B_o (or B'_o) is its intersection point with this axis. Consider two rays indefinitely close to PB in the sagittal plane, incident at P_s. Since the distance of these two rays from the auxiliary axis differs by an insensibly small amount from the distance of PB therefrom, the spherical aberration, with respect to the auxiliary axis, must be the same for all three rays. Hence all three rays will cut the auxiliary axis at the same distance from the refracting surface. And since, before refraction, the two sagittal rays converged on the chief ray at B_o where it cut the auxiliary axis, they must, after refraction, converge upon the chief ray at B'_o.

We put PB_o = s; PB'_o = s′; we put the angle PCQ = O, then we have angle PB_oQ = O—I and angle PB'_oQ = O—I′. From trigonometry we have the law that the sides of a triangle are to each other as the sines of their opposite angles, hence

$$\frac{r}{s} = \frac{\sin(O-I)}{\sin(180°-O)}, \qquad \frac{r}{s'} = \frac{\sin(O-I')}{\sin(180°-O)}.$$

And, since sin (x ± y) = sin x cos y ± cos x sin y, and sin (180° − x) = sin x, we have

$$\frac{r}{s} = \frac{\sin O\cos I - \cos O\sin I}{\sin O} = \cos I - \sin I\,\text{cotan O};$$

$$\frac{r}{s'} = \frac{\sin O\cos I' - \cos O\sin I'}{\sin O} = \cos I' - \sin I'\,\text{cotan O}.$$

To eliminate sin O, we multiply the first equation by sin I′ and the second by sin I, subtract the first from the second, and obtain

$$\frac{r\sin I}{s'} - \frac{r\sin I'}{s} = \sin I\cos I' - \cos I\sin I'.$$

If we multiply the first term on each side by N′/r sin I, and the second term on each side by N/r sin I′ (which is valid because N/r sin I′ = N′/r sin I, by the law of refraction), we obtain:

$$s' = N'/\left(\frac{N'\cos I'}{r} - \frac{N\cos I}{r} + \frac{N}{s}\right).$$

We now have the necessary equations for computing t′ and s′, using data from Table VII for our previously traced chief ray. But we must first give our attention to equations for transfer from one surface to the next.

(Continued in October)

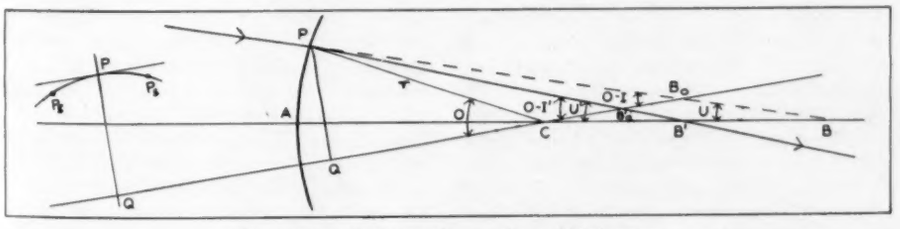

Fig. 15. Astigmatism of sagittal rays.

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It summarizes our knowledge of comets, meteors, asteroids and meteorites, describes the latest discoveries and considers problems yet unexplained. 106 Illus. 222 Pages. $2.50. (1941) By *F. G. Watson.*

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BOOKS AND THE SKY

PHYSICS AND PHILOSOPHY

Sir James Jeans. The Macmillan Company, New York, 1943. *222* pages. $2.75.

QUITE a few students of the physical sciences, particularly of astronomy, feel nowadays that they need to know a little about philosophy. It is generally recognized that physical theories like relativity or the quantum theory cannot be properly understood if the ties between the purely physical statements and their philosophical implication are ignored. It is recognized, too, that just these physical theories have played an important part in the recent advances in astronomy.

If a man like Sir James Jeans, whose whole life has been devoted to the advance of physics and astronomy, is willing to be a guide in the approach to philosophy, the student of astronomy will be, certainly, delighted to avail himself of this guidance. He will be delighted still more if he takes into account Jeans' extraordinary ability in the presentation of scientific subjects to people who love science but are not familiar with the technicalities of the professional scientist. Therefore, this book seems to be an excellent opportunity for the amateur astronomer to learn something about the philosophical questions which arise naturally from his favorite subject.

However, it would be erroneous to think that the ties between physics and philosophy have been particularly tight in our 20th century. When Copernicus and Galileo advanced their new doctrines which claimed to replace the doctrines of medieval science, no scientist of that time would doubt that a new philosophy also had been born. Newton was regarded by his contemporaries as a philosopher as well as a mathematician. For a long time, no boundary line existed between theoretical physics and philosophy. Only in the 19th century did a certain separation take place. For then the general belief prevailed among scientists that the Newtonian laws were the established laws of nature for all the future. All further scientific work would only consist in drawing special conclusions from these established principles. In this way science would no longer have to do with the principles themselves and would lose all philosophical interest. The revolutionary theories of the 20th century restored the philosophical role of theoretical physics. As a matter of fact, the student of physical science has need for an understanding of philosophical problems every time he has to face radically new physical theories which mean a change not only in the results but in the principles themselves.

The purpose of the present book is to meet this need of the science student. In Chapter I, "What are physics and philosophy?" the author leads us immediately into the very center of the issue.

"The study of physics," Jeans says, "has driven us to the positivist conception of physics. We can never understand what events are but must limit ourselves to describing the pattern of events in mathematical terms. No other aim is possible. . . . Physics tries to discover the pattern of events which controls the phenomena we observe. We can never know what this pattern means, and even if some superior intelligence were to tell us we should find the explanation unintelligible."

Here the voice of the scientist Jeans is speaking. It is the voice of a positivist of the most radical kind. But after the passages quoted above, Jeans adds: "Our study can never put us in touch with reality." Here we listen to the voice of the "mysterious" philosopher Jeans. But if science is not the way to reality, what else is the way?

"Whenever science leaves off," Jeans continues, "then philosophy begins. The boundary is clearly defined, at least if we accept the positivist view of physics. The task of physics is to discover and formulate laws while that of philosophy is to interpret and discuss." But this task of philosophy seems not to have much prospect of success. We hear again the voice of Jeans the scientist saying: "But the physicist can warn the philosopher that no intelligible interpretation of the working of nature is to be expected." All that we can expect of philosophy would then be an unintelligible interpretation.

In Chapter II, "How do we know?" Jeans gives a survey of the opinions of philosophers about how we can know something about the objective world. We learn the doctrines of men like Descartes, Leibniz, Kant, and wind up with Eddington. This chapter contains a very convincing criticism of the blunders made by philosophers in their delusive striving for "a priori knowledge," for a knowledge which would be independent of experience and based upon mere reasoning. Chapter III takes up the issue of Chapter I in a more elaborate way. Jeans enumerates by instances the basic differences in the approach of the physicist and the philosopher to the problems of nature. Chapters IV, V, and VI give a historical survey of the evolution of the physical world picture.

Here Jeans discusses in particular the philosophical interpretations of the quantum theory which have played a great role in the philosophy of the 20th century. This theory was put into the service of highly metaphysical doctrines: the freedom of will, the co-existence of mind and matter, the idealistic world picture according to which the background of the universe is mind.

Jeans' book is, certainly, very helpful as information about all these interpretations. However, the ambiguous character of his whole approach becomes conspicuously evident in his approach to the metaphysical implications of the quantum theory. Nowhere does Jeans tell the reader clearly and explicitly: If we stick to a consistent scientific view, the quantum theory cannot teach us anything whatsoever about freedom of will, about the mental background of the world, and so on. All these doctrines are extra-scientific and arise from sources inde-

pendent of the theories of the 20th century. This ambiguous attitude becomes particularly clear in the final Chapter VII, "Some problems of philosophy."

At one place, the author gives a philosophical interpretation of relativity and the quantum theory which sounds like straight mysticism:

"So far as the inanimate world is concerned, we may picture a substratum below space and time in which the springs of events are concealed, and it may be the future already lies hidden, but uniquely and inevitably determined, in this substratum." Although this passage seems to be quite obscure from the viewpoint of science, Jeans assures us bluntly that "such a hypothesis at least fits all the known facts of physics." And then he continues in his mysterious vein: "But as we pass from the phenomenal world of space and time to the substratum, we seem, in some way we do not understand, to be passing from materialism to mentalism, and so possibly also from matter to mind."

And then Jeans proceeds to the climax of interpretation by obscure words. He continues: "It may be that the springs of events in this substratum include our own mental activities, so that the future course of events may depend in part on these mental activities."

After this interpretation, which tries to satisfy the requirements of the traditional philosopher, the cautious and critical scientist Jeans again takes the floor, and his conclusion of the book sounds prudent and rather skeptical:

"We can hardly say that the new physics justifies any new conclusions on determinism, causality or free will, but we can say that the argument for determinism is in some respect less compelling than it seemed to be fifty years ago. There appears to be a case for reopening the whole question as soon as anyone can discover how to do so." Since the author himself obviously does not claim to have discovered "how to do so," the philosophical result is very modest.

"This may seem," concludes Jeans, "a very disappointing harvest . . . yet we may reflect that physics and philosophy are at most a few thousand years old. . . ."

In spite of the brilliant style of this book and its great value as a source of information, it is in a certain way disappointing. The greatest educational values which a student of science can draw from the philosophical angle of science are the training in logical thinking and a more profound understanding of the respective roles of logic, imagination, and experience in the advance of science; of these values very little is available in the present book. Nowhere is a real attempt made to tell clearly and distinctly that there is no science beyond science and that any "interpretation of science" is either a part of science itself or a pure description of the emotions accompanying the study of science.

Jeans fails to make clear this distinction and he may, therefore, even contribute occasionally to the confusion of those students of science who are attracted by the positive qualities of the book.

PHILIPP FRANK
Harvard University

THE AMATEUR SCIENTIST

W. Stephen Thomas. W. W. Norton and Co., Inc., New York, 1942. 283 pages. $3.00.

MR. THOMAS, as executive secretary of the Committee on Education and Participation in Science of the American Philosophical Society, had valuable experience for the compilation of a volume such as this. For here is a crystallization of the efforts of amateur observers in all fields. The book thus commands recognition for the many individuals whose unpretentious, but nevertheless patient and thorough work on their hobbies comprises a bridge between the layman and the professional.

Philadelphia is used as the sample city for discussion. It is interesting to note that there astronomy ranks among the first choices of hobbyists. The author briefly describes the histories and current activities of the Rittenhouse Astronomical Society and The Franklin Institute amateurs, whose specialty is telescope making.

However, not much space is actually devoted to recreational pursuits as such. Rather, the book goes at length into organizations and their relation to a given community. The association of members, research possibilities, the business of procuring speakers, field trips, educational assets, and other functions are discussed. Attention is called to the fact that better recording and publication of data would bring a much-needed fusing of the results of amateur study by groups all over the country.

The Amateur Scientist concludes with suggested programs for popular scientific investigation, and provides in the appendices specific work sheets for these projects. Viewing the future, Mr. Thomas declares that more recognition for the amateur is necessary from public and professional circles.

PETER A. LEAVENS
Amateur Astronomers Association

Sauce for the Gander

READERS are asked to send in questions, from which this editor will select the best each month to answer here. The last question is left unanswered, but the reader should be able to find the answer for himself. This month's questions come from Hubert Swoboda and Caryl Annear.

Q. If everything else remained unchanged, and the direction of the earth's rotation were reversed, why would we have two extra days in the year, and why would our watches run fast by eight minutes a day?

A. The earth makes 366¼ rotations on its axis every year, so there are 366¼ sidereal days in a year. But if the earth did not rotate at all there would still be one day and one night every year as the earth is carried around the sun by its revolution. The combined effect is that there are 365¼ days and nights in a year, or 365¼ solar days. If either the rotation or revolution were reversed in direction, but not both, the two phenomena would be added instead of subtracted, and there would be 367¼ days in a year, with each day nearly eight minutes shorter than at present.

Q. Two rates of travel are given for the sun, one at 12 miles a second and one varying from 150 to 200 miles a second. Which is correct? Do the rates of travel refer to the movement of the sun toward the apex of its way? Is this movement the same as its revolution about the galactic center?

A. The lesser rate is calculated from the change of position of the sun in relation to the nearer stars, and is considered as motion in a straight line, toward the apex of the sun's way in Hercules, first noted by Sir William Herschel. The stars involved in this calculation form a very small part of the galaxy. This first motion may be likened to the individual movements of the bees in a swarm, while the swarm moves through space.

Later investigation of the radial velocities of more distant objects showed that they are all circling around a common galactic center, which is located in the direction of Sagittarius and about 30,000 light-years from the sun. The rate of motion is figured on the basis of maintenance of the Milky Way galaxy's structure according to the principles of gravitation, and gives the larger velocity mentioned in the question.

Q. What is the meaning of the term magnitude? L. J. LAFLEUR

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Some Methods for Emergency Navigation

THE FACT that several astronomers, notably Dr. Charles H. Smiley, of Brown University, and Dr. Bart J. Bok, of Harvard University, have taken up the problem of navigation in emergencies indicates its growing importance. The former's methods, as outlined in recent issues of **Popular Astronomy,** assume very little prior knowledge of navigation on the part of those who use the tables and maps which he would provide in every life raft.

On his map of the world, I would like to suggest the inclusion of isogonic lines (showing the compass error in different parts of the world) and symbols at small islands in the Pacific showing whether or not a particular island is inhabited and whether or not there is any means of communication with the outside world.

A recent experience makes me want to add a knife or pencil-sharpener to the equipment, also! In rough air, the points broke on all my pencils, but luckily, another member of the crew had a knife.

In regard to star charts, the use of the Rude Star Finder might require very little added space, and would enable determination of the azimuths of the stars — knowledge of considerable value if no compass is at hand.

In the matter of determining the latitude by variation in the length of the day from sunrise to sunset, Dr. Smiley suggests that local noon be determined also, in the event sunrise or sunset is not visible. His tables are sufficiently accurate to determine latitude within 30 nautical miles, except near the equinox times of the year. The noon determination, together with a watch which is keeping a known kind of time, permits an approximation of the longitude.

In case it is desired to use stars instead of the sun, the risings and settings are not so easily observed, especially at sea. If the horizon is visible, however, as on a moonlit night, we may apply the fact that a star crosses the meridian halfway between the time it attains a given altitude when rising and the time it reaches that altitude again when setting. We do not need a sextant for this, making use of the same methods of measurement as Dr. Smiley applies to determine distance from the substellar point. In fact, if the same object (stick, ruler) is used for both measurements, **we do not even need to know what the altitude is.** But our tables should include the right ascensions of the stars (say 1st and 2nd magnitude) and the sidereal time of 0^h at Greenwich, together with a conversion table. By this means, longitude may be found as easily and as accurately as by the sun.

This is simply a crude adaptation of the ancient method of **time by equal altitudes** used by the mariner of Bowditch's time. For accurate work, it was necessary to apply the "equation of equal altitudes" to the time so obtained, but this is not needed in emergency circumstances.

In the problem of latitude, for which Dr. Smiley uses the sun, as already noted, stars may be used also, by either of two methods, one almost entirely unknown among navigators. Consider the simplest method first.

The **semidiurnal arc** measures half the time that a body remains above the horizon. It bears a definite relationship to the declination of the body and the latitude of the observer, as follows:

$$\cos \mathbf{t} = -\tan \mathbf{L} \tan \mathbf{d},$$

where **t** is the semidiurnal arc, **L** is the latitude, and **d,** the declination. If trigonometric tables are at hand, the latitude may be computed by this formula, but Bowditch has given a table in which the latitude and declination are supposed known, to find the semidiurnal arc. This may be used in reverse, and will yield the latitude to the nearest even degree, if the observations are good.

The second method is more accurate, but it has never been popular. To my knowledge, the only book on navigation containing this method is Muir's **Navigation and Compass Deviations** (U. S. Naval Institute, 1918), a book formerly used at Annapolis. The only other work I can find it in is Chauvenet's **Spherical and Practical Astronomy,** Vol. I, Art. 199 and 207. It was originated by Prestel, and Chauvenet says of it:

"This is evidently but a rough method, only to be resorted to in cases of emergency. With the greatest care in observing the contacts, and in latitudes not less than 45°, the result cannot be depended upon within from five to ten minutes; but even this degree of accuracy may, in many cases at sea, be quite satisfactory."

We shall not presume the method to be more accurate than to the nearest degree. It requires trigonometric tables, or a special table computed in advance in case the sun is used. Its basic formula is:

$$\cos \mathbf{L} = \mathbf{S} \operatorname{cosec} \mathbf{A}/15\mathbf{T},$$

where **L** is latitude, **S** is difference in altitude, **A** is azimuth, and **T** is elapsed time. If **T** is in seconds of time, **S** must be in seconds of arc.

This method depends upon the rate of change of a body's altitude, but it does require the azimuth to be known, at least approximately. This makes Rude's Star Finder useful at night, or a compass at any time — the same as needed to steer one's course, as pointed out by Dr. Smiley. The observations of stellar altitudes may be made by his methods also, but in the case of the sun, the altitude itself need not be known.

This is similar to our previous suggestion regarding equal altitudes. Suppose, during the morning, we sight the upper limb of the sun with some object held at arm's length. We continue to watch until the lower limb is upon our sight. Then the change in altitude has been equal to the sun's diameter. If a simple table of the solar diameter for various dates during the year is available, the altitude change may be found exactly; otherwise, it may be presumed to be roughly 30 minutes of arc. The elapsed time is measured by our watch, **or it may even be approximated by counting seconds.** So here is a case where one may navigate without a watch, if he has a compass instead!

A further simplification may be applied if the sun is observed when it bears due east or west, for the term cosec **A** is then equal to 1. Also, since the sun's diameter is roughly 1,800 seconds, the equation may be approximated by $\cos \mathbf{L} = 120/\mathbf{T}$. It is better, however, to use the sun's actual diameter, if available, divided by 15 as in the original form of the equation.

All this is very simple, and lends itself to a table similar to those proposed by other methods of emergency navigation. The table would have 12 columns, one for every month, each using the average value of the solar diameter for that month. The other argument would be the elapsed time, and the latitude would be read directly from the table.

Of course, in the case of the stars, such simplification would not be so easy to achieve, but simple trigonometrical tables would make use of this method possible, and it might prove valuable under certain conditions.

Perhaps it is time someone, inexperienced in navigation, really got "lost" while equipped to practice various emergency navigation methods. The relative values of the many current proposals might be definitely determined, or each of them proven to be necessary under certain differing sets of circumstances.

S. S.

AUGUST ECLIPSES

OUR soldiers and friends in Australia have opportunity to see two eclipses this month, both partial, one of the sun on August 1st, and the other of the moon on August 15th.

The solar eclipse will really be annular, but the path of the annular track will be entirely over the ocean to the southwest of Australia, just missing the continent itself. Maximum duration of the annulus will be seven minutes.

The lunar eclipse, in which seven eighths of the moon's diameter will be obscured, will be observed principally in Australia, Asia, Africa, and southern Europe. Mid-eclipse will come at $19^h\ 28.4^m$ Universal time, while three hours will elapse from first to last umbral contacts.

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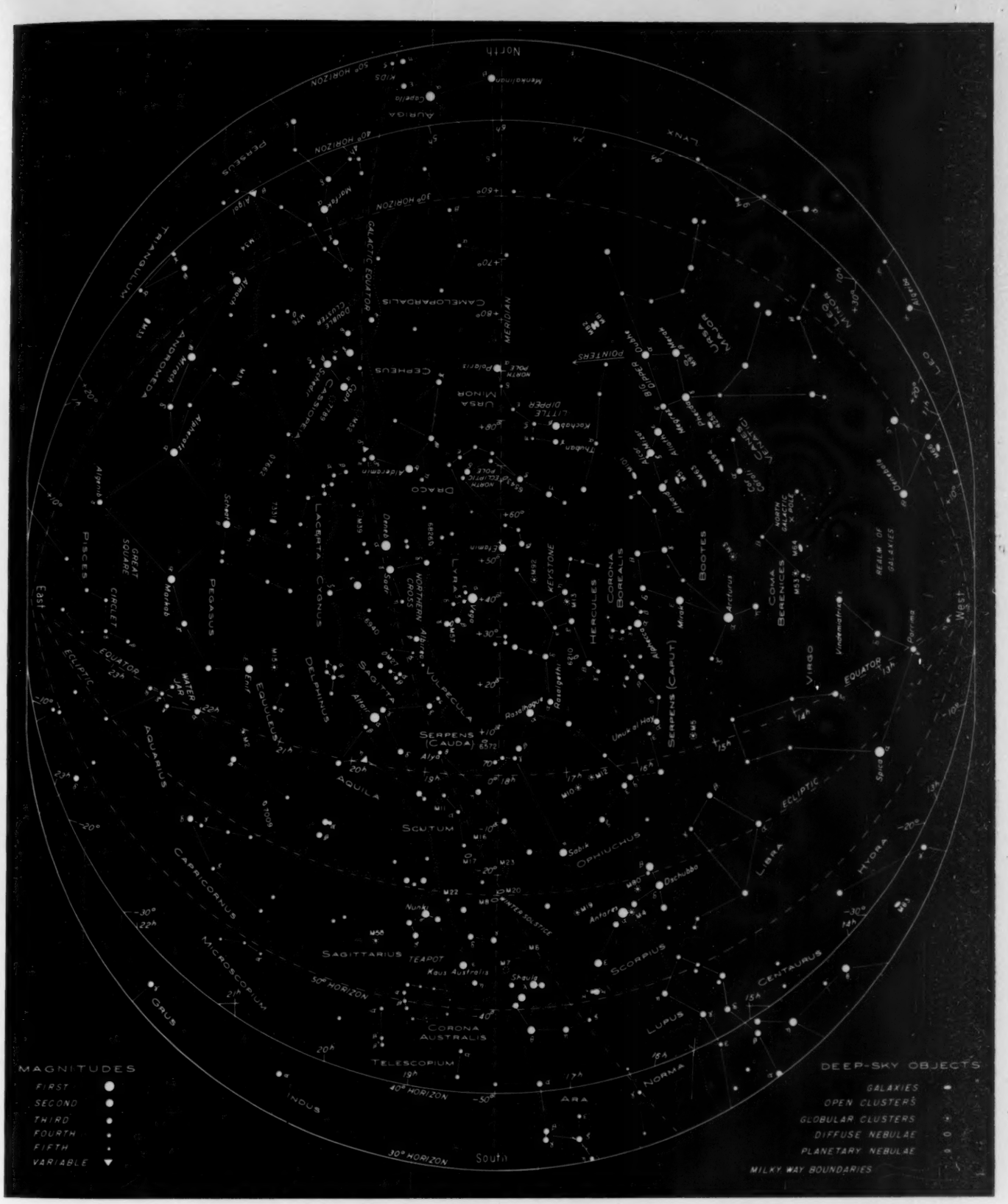


DEEP-SKY WONDERS

THIS month finds the following objects in good position for observation with moderate-sized telescopes. The descriptions are adapted from Norton's **Star Atlas.**

Sagittarius. M23, 17h 54.0m, —19° 1′; an open cluster, containing stars from 9th to 13th magnitude. A fine low-power field, as the cluster is 47′ in diameter. M8, 18h 0.6m, —24° 23′; the Lagoon nebula, visible to the naked eye. An ill-defined nebulosity with dark patches and stars, followed by an irregular open cluster. To the northwest is M20, the Trifid nebula, pictured on the back cover this month. M17, 18h 18.0m, —16° 12′; the Omega or Horseshoe nebula, bright and large, with a long bottom streak. M22, 18h 33.3m, —23° 57′; a large, bright globular cluster, about 15′ in diameter.

Scutum. M11, 18h 48.2m, —6° 20′; a fan-shaped cluster, with a bright star at the apex, and dark nebulosity to the south.

THE STARS FOR AUGUST

as seen from latitudes 30° to 50° north, at 10 p.m. and 9 p.m. on the 7th and 23rd of the month, respectively. The 40° north horizon is a solid circle; the others are circles, too, but dashed in part. When facing north, hold "North" at the bottom, and similarly for other directions. This is a stereographic projection, in which the flattened appearance of the sky itself is closely reproduced, without distortion.

OBSERVER'S PAGE

All times mentioned on the Observer's Page are Eastern war time.

Venus at Greatest Brilliance — II

By Jesse A. Fitzpatrick

THE INTERESTING period of Venus' brightness, extending from greatest elongation east to greatest elongation west, lasts for approximately 144 days and is divided into four intervals of 36 days each. There is always a slight modification of these figures due to the varying speeds of the planets as they revolve around the sun. The inclination to the ecliptic of the orbit of Venus also partly accounts for this irregularity. At the beginning and ending of the 144-day period, the planet, then about 65 million miles from the earth, appears to us as the moon does at the quarter phase. At this moment, the angle between the sun and the earth as seen from Venus is 90°. As the angular diameter of the planet at this distance is 24″, a simple computation shows that the illuminated area, one half of the apparent disk, equals 226 square seconds. This condition prevailed on June 27th.

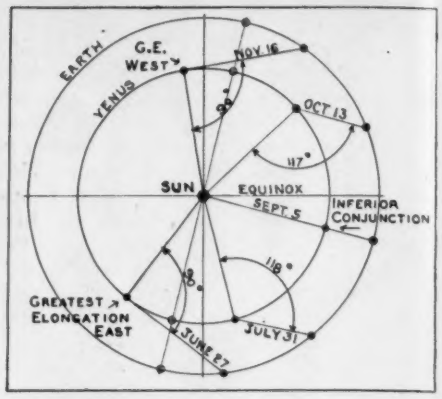
As the earth and Venus move in a counterclockwise direction, the angle of 90° will increase until it becomes 180° on September 5th. The sun and the two planets are in alignment on that date, as shown in the diagram. The faster-moving Venus requires 72 days, or one half of the 144-day period, to catch up with the earth and so bring about this situation. This alignment, known as inferior conjunction, is in celestial longitude only. Due to the inclination of Venus' orbit, the planet's celestial latitude on September 5th will be 8° south (of the ecliptic), or to put it in simpler words, if we on the earth could see Venus on that day, it would be 8° south of the sun's center.

When the alignment is in both longitude and latitude, we can observe Venus as it moves across the sun's disk — a transit of Venus. This is a very rare occurrence; the latest pair was in 1874 and 1882, and the next will take place in 2004 and 2012.

While Venus is moving toward inferior conjunction, its illuminated half moves toward the hemisphere that is farthest from us, and this is completed on September 5th, when the near side of the disk is dark. Because the apparent position of Venus is 8° south of the sun we would, however, still see a tiny crescent of light at the top of the disk if the glare of the sun did not interfere.

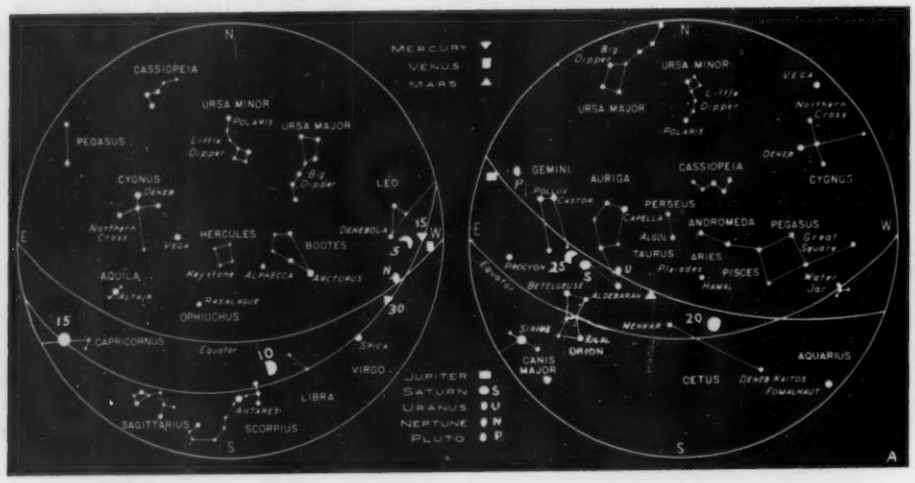
From the diagram, it is easy to see that the separation of Venus and the earth decreases during the 72-day period, from 65 million miles at greatest elongation to 26,500,000 at inferior conjunction. While this is going on, the angular diameter of Venus increases from 24″ to 59″, thereby enlarging the area of the disk sixfold. But we must also consider that although this area grows larger, the portion of it that is illuminated decreases. I have previously noted that on June 27th the illuminated area equals 226 square seconds. On July 1st, when the planet has moved more than two million miles closer to the earth, the apparent diameter has increased to 25″, but the illuminated portion has decreased from 50 to 47 per cent. We now find that 231 square seconds of the disk are reflecting the sun's light and the planet appears brighter. This progression continues until at the end of 36 days, one fourth of the 144-day period, or July 31st, the diameter has increased to 38″, and the illuminated area has decreased to 26 per cent. At this time, 298 square seconds of the disk are lighted by the sun, and the planet will be at the stage of greatest brilliancy. Its distance from the earth has decreased to 41 million miles. At this moment the angle between the earth and the sun, as seen from Venus, will have increased to 118°. Over a period of many years the average of the angle will be 117°.5.

During the next 36 days, or until inferior conjunction on September 5th, the illuminated portion decreases each day. On August 5th it is reduced to 292 square seconds, and on September 5th, only 22



The relative positions of Venus and the earth during this summer and autumn are shown here. Note that Venus moves about 3/5 of the way around its orbit in going from greatest eastern to greatest western elongation.

THE MOON AND PLANETS IN THE EVENING AND MORNING SKIES



In mid-northern latitudes, the sky appears as at the right at 6:30 a.m. on the 7th of the month, and at 5:30 a.m. on the 23rd. At the left is the sky for 8:30 p.m. on the 7th and for 7:30 p.m. on the 23rd. The moon's position is marked for each five days by symbols which show roughly its phase. Each planet has a special symbol, and is located for the middle of the month, unless otherwise marked. The sun is not shown, although at times it may be above the indicated horizon. Only the brightest stars are included, and the more conspicuous constellations.

Mercury will reach greatest elongation east, 27° 17′, on August 29th. Its path, 13° south of the sun's path, will make this elongation more attractive to observers in the Southern Hemisphere than in the Northern. The planet should be watched for on the evening of the 28th.

Venus. See special article in this issue.

Mars, in Aries and Taurus, will reach magnitude 0.0 at the end of the month. It will then rise in the northwest a half hour before midnight, near the Hyades.

Jupiter is too close to the sun for observation.

Saturn and Uranus are morning stars in Taurus.

Neptune is too close to the sun for observation.

AUGUST METEORS

The Perseid meteor shower should reach its maximum about the 12th, but members of the swarm may be seen for many days before and after that date. Although they radiate from Perseus, these meteors may appear in any part of the sky, even when the constellation is not above the horizon.

PHASES OF THE MOON

New moon	August	1,	0:06 a.m.
First quarter	August	8,	11:36 p.m.
Full moon	August	15,	3:34 p.m.
Last quarter	August	22,	12:04 p.m.
New moon	August	30,	3:59 p.m.

square seconds are reflecting sunlight. The latter figure, of course, would be zero if it were not for the inclination of Venus' orbit.

Following inferior conjunction, conditions will be reversed, and the planet will gradually grow brighter while it emerges from the sun's glare as a morning star. At the end of the next 36-day period it will again attain greatest brilliancy. This will occur on October 13th, when Venus will be slightly brighter than on July 31st, as it will be a little nearer the earth; the stellar magnitude will be —4.3.

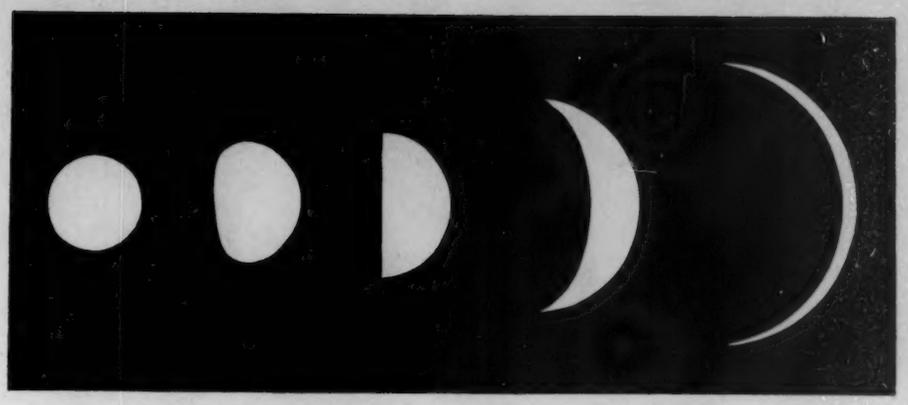
At the end of the fourth 36-day period, the angle between the sun and the earth as seen from Venus again becomes 90°, and the latter is at greatest western elongation. This will occur on November 16th, when the planet will once more resemble the moon at the quarter phase.

An inspection of the diagram will show why the angular distance between the sun and Venus is approximately 45° when Venus is at greatest elongation east or west. Under certain conditions, the angle is as large as 48°. As mentioned earlier in this article, the distance between Venus and the earth at these times is close to 65 million miles. Since the mean distance of Venus' orbit from the sun is 67 million miles, we have a right-angle triangle with two nearly equal sides, so the angles opposite these sides approximate 45° each.

Closer examination will show why the planet can never be farther than this angular distance from the sun. Whether Venus is moved backward or forward in the orbit, the apparent distance between it and the sun will be less than the true radial distance of 67 million miles which we see at elongation.

On November 3rd, Venus will again cross the ecliptic, this time from south to north, at the point known as the ascending node. On the diagram, I have designated the nodes of Venus' orbit by small open circles; the ascending node is near the top. Opposite these nodes on the earth's orbit the small open circles show the earth's positions when passing the nodes. At these times it is possible to observe a transit of Venus across the face of the sun. Although the earth passes the nodes of Venus' orbit in the early part of June and December each year, about two weeks before the solstice in each case, for a transit to occur Venus must be at its node on the same date; the infrequency with which this happens is shown by the long intervals between pairs of transits.

The synodic period of Venus is 584 days, although its revolution around the sun is completed in 225 days. Thus, 440 days will elapse while the planet passes from greatest western elongation through superior conjunction with the sun and around to greatest eastern elongation, reaching that position again late in January, 1945.



As Venus revolves around the sun, it has phases like the moon's, accompanied by a variation in apparent size, as pictured above. The "full" phase occurs when the planet is on the far side of its orbit, so it has the smallest apparent size. The "half" phase occurs at greatest elongation, but the crescent grows larger until Venus swings through inferior conjunction, when the planet is nearest to us.

OCCULTATIONS—AUGUST, 1943

Local station, lat. 40° 48'.6, long. 4h 55.8m west.

Date	Mag.	Name	Immersion	P.*	Emersion	P.*
Aug. 8	5.8	13 Librae	7:52.0 p.m.	99°	9:11.6 p.m.	304°
13	5.1	36 Sagittarii	1:16.6 a.m.	84°	2:23.3 a.m.	260°
19	6.2	26 Ceti	4:53.4 a.m.	60°	6:10.3 a.m.	243°
21	4.3	f Tauri	11:37.6 p.m.	47°	0:27.9 a.m. (22)	276°
23	6.4	70 Tauri	1:14.8 a.m.	75°	2:14.2 a.m.	248°
23	4.0	Theta[1] Tauri	2:52.3 a.m.	130°	3:25.1 a.m.	192°
23	5.3	75 Tauri	2:55.5 a.m.	30°	3:49.4 a.m.	292°
23	4.8	264 B Tauri	3:53.2 a.m.	108°	4:52.7 a.m.	212°
25	5.2	71 Orionis	4:55.2 a.m.	121°	5:49.9 a.m.	218°

*P is the position angle of the point of contact on the moon's disk measured eastward from the north point.

★ ★

PLANETARIUM NOTES

Sky and Telescope is official bulletin of the Hayden Planetarium in New York City and of the Buhl Planetarium in Pittsburgh, Pa.

★ **THE BUHL PLANETARIUM** presents in *August*, BY ROCKET TO THE MOON.

Have you not longed at some time to journey to the nearest of the heavenly bodies, the beautiful but mysterious little moon, and see its wonders? Here's your chance, as the Buhl Planetarium offers interplanetary rocket service this month in the 21st century. We find ourselves in a luxurious space liner which whisks us to the moon in a few thrill-crowded minutes. Before landing, we explore the moon's mountainous surface and study at close range the strange craters and seas, the weird and colorful scenery. While we are landed on the floor of a lunar crater, many adventures befall us. We see our own earth hanging in the sky amongst the stars—see it eclipse the sun as we suddenly are plunged into the earth's red shadow. At length our rocket turns about and carries us home.

★ **THE HAYDEN PLANETARIUM** presents in *August*, THE ANSWER'S IN THE SKY. (See page 12.)

In *September*, SAILING THE SEVEN SEAS. Beginning with the dramatic episode of Columbus' landfall vividly portrayed on the planetarium sky, we shall trace down to the present the development of the principles underlying methods used by the navigators of sea and air. Special projection recordings and transcriptions will be freely used to help tell the story.

★ SCHEDULE BUHL PLANETARIUM

Mondays through Saturdays (except Tuesdays).....3 and 8:30 p.m.
Sundays and Holidays.....3, 4, and 8:30 p.m.
(Building closed Tuesdays)

★ STAFF—*Director*, Arthur L. Draper; *Lecturer*, Nicholas E. Wagman; *Manager*, Frank S. McGary; *Public Relations*, Robert F. Hostetter; *Chief Instructor of Navigation*, Fitz-Hugh Marshall, Jr., *Instructor, School of Navigation*, Edwin Ebbighausen.

★ SCHEDULE HAYDEN PLANETARIUM

Mondays through Fridays.....2, 3:30, and 8:30 p.m.
Saturdays.....11 a.m., 2, 3, 4, 5, and 8:30 p.m.
Sundays and Holidays.....2, 3, 4, 5, and 8:30 p.m.

★ STAFF—*Honorary Curator*, Clyde Fisher; *Curator*, William H. Barton, Jr.; *Associate Curator*, Marian Lockwood; *Assistant Curator*, Robert R. Coles (on leave in Army Air Corps); *Scientific Assistant*, Fred Raiser; *Lecturers*, Charles O. Roth, Jr., Shirley I. Gale, John Saunders.